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Traffic Safety
Administration**

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Final Report

Braking Performance of Thirteen Light Trucks

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16. Abstract

A Supplemental Notice of Proposed Rulemaking (SNPRM) has recently been issued for a braking regulation for passenger cars (FMVSS 135 Notice 4). This report describes testing of light trucks (not currently included in the rulemaking) to the proposed FMVSS 135 Notice 4 procedure in order to investigate the feasibility of using the procedure for these vehicles and to develop a data base for future rulemaking. Additionally, tests were conducted to measure the brake balance and the center of gravity heights of the vehicles. Thirteen vehicles were tested to cover the range of size and configuration. The report includes discussions of the tests vehicles, test site, test procedures and test results.

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Department of Transportation
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TECHNICAL SUMMARY

Report Title

Braking Performance of Thirteen Light Trucks April 1988

Report Author(s)

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A Supplemental Notice of Proposed Rulemaking (SNPRM) has recently been issued for a braking regulation for passenger cars (FMVSS 135 Notice 4). This report describes testing of light trucks (not currently included in the rulemaking) to the proposed FMVSS 135 Notice 4 procedure in order to investigate the feasibility of using the procedure for these vehicles and to develop a data base for future rulemaking. Additionally, tests were conducted to measure the brake balance and the center of gravity heights of the vehicles. Thirteen vehicles were tested to cover the range of size and configuration.

In testing the vehicles to the proposed FMVSS 135 Notice 4 test procedure, no problems were found which would suggest the need for a change in the procedure to accommodate light trucks. A comparison of the light trucks and a set of 19 passenger cars tested to the same procedure showed that the difference in average performance was less than 11 percent in all of the test sections.

The brake balance of the light trucks indicate that most would lock their front wheels first when fully loaded. In the unladen condition, a number of the vehcles would be rear brake biased on many surfaces. In both cases, the braking efficiencies were greater than 70 percent.

Braking Performance of Thirteen Light Trucks

1.0 INTRODUCTION

The National Highway Traffic and Safety Administration (NHTSA) has recently issued a Supplemental Notice of Proposed Rulemaking (SNPRM) for a braking regulation for passenger cars (FMVSS 135, Notice 4). The purpose of this rulemaking action is to develop an internationally harmonized standard. A more detailed description of the harmonization effort and results of five test programs on versions of proposed harmonized procedures are given in References 1 through 5. While efforts to date have centered on only passenger cars, the next area of interest will probably be light trucks. Additionally, front/rear brake balance, adhesion utilization characteristics, and center of gravity height information are also of interest for light trucks.

In order to investigate the feasibility of using the proposed FMVSS 135 Notice 4 test procedure for light trucks and also to develop a data base for any future rulemaking, 13 light trucks were tested to the Notice 4 procedure. Brake balance and center of gravity heights were also measured on the same set of vehicles. The report which follows describes the tests on these 13 vehicles and the results of these tests. Comparisons of these results to the results for 19 passenger cars tested to the same procedure (discussed in Reference 5) will also be made.

All of the testing was performed at the NHTSA's Vehicle Research and Test Center (VRTC) which is located at the Transportation Research Center (TRC) of Ohio.

Section 2 of the report describes the test conditions. Section 3 gives the results of the tests to the FMVSS 135 Notice 4 procedure. Section 4 of the report describes the center of gravity measurements and Section 5 gives the results of the brake balance tests. A summary and conclusions is given in Section 6.

2.0 TEST CONDITIONS

This section of the report describes the test site, the test vehicles and the instrumentation used for the tests.

2.1 Test Site

All of the tests were conducted at the Transportation Research Center (TRC) of Ohio. Figure 1 is an aerial veiw of the TRC track facilities. The Skid Pad was utilized for most of the testing. The Skid Pad is 9,000 feet long overall with a 0.5% slope (from North to South) and has a 309 foot radius loop at each end for vehicle turn around. Length of the 6-lane wide test area is 2,500 feet. Several different surfaces are available on the Skid Pad. Two of the skid pad surfaces were used for these tests. The surface on which most of the testing was conducted is a concrete surface having a dry ASTM skid number of 80 nominal. The other surface is a polished concrete surface having a wet ASTM skid number of 50 nominal. Both skid numbers were determined with a 15 inch ASTM tire at 40 mph. The dry surface was used for the straight line stopping distance tests and the 50 SN surface was used for axle lockup sequence tests

The 50 acre Vehcile Dynamics Area has a portion of the area coated with Jennite, a driveway sealer. The Jennite was used for low mu stopping distance tests and axle lockup sequence tests. The Jennite area has a wet ASTM skid number of 20 nominal as determined with a 15 inch ASTM tire at 40 mph.

The skid numbers listed represent 100 times the sliding coefficient of friction between the surface and the standard ASTM tire. A peak coefficient of friction or mu value will generally be higher than the skid number and will have a different value for different tires. Past testing has shown that with passenger car tires the peak mu for the 50 SN surface is in the 0.8 to 0.9 range and for the 20 SN surface it is in the 0.4 to 0.6 range.

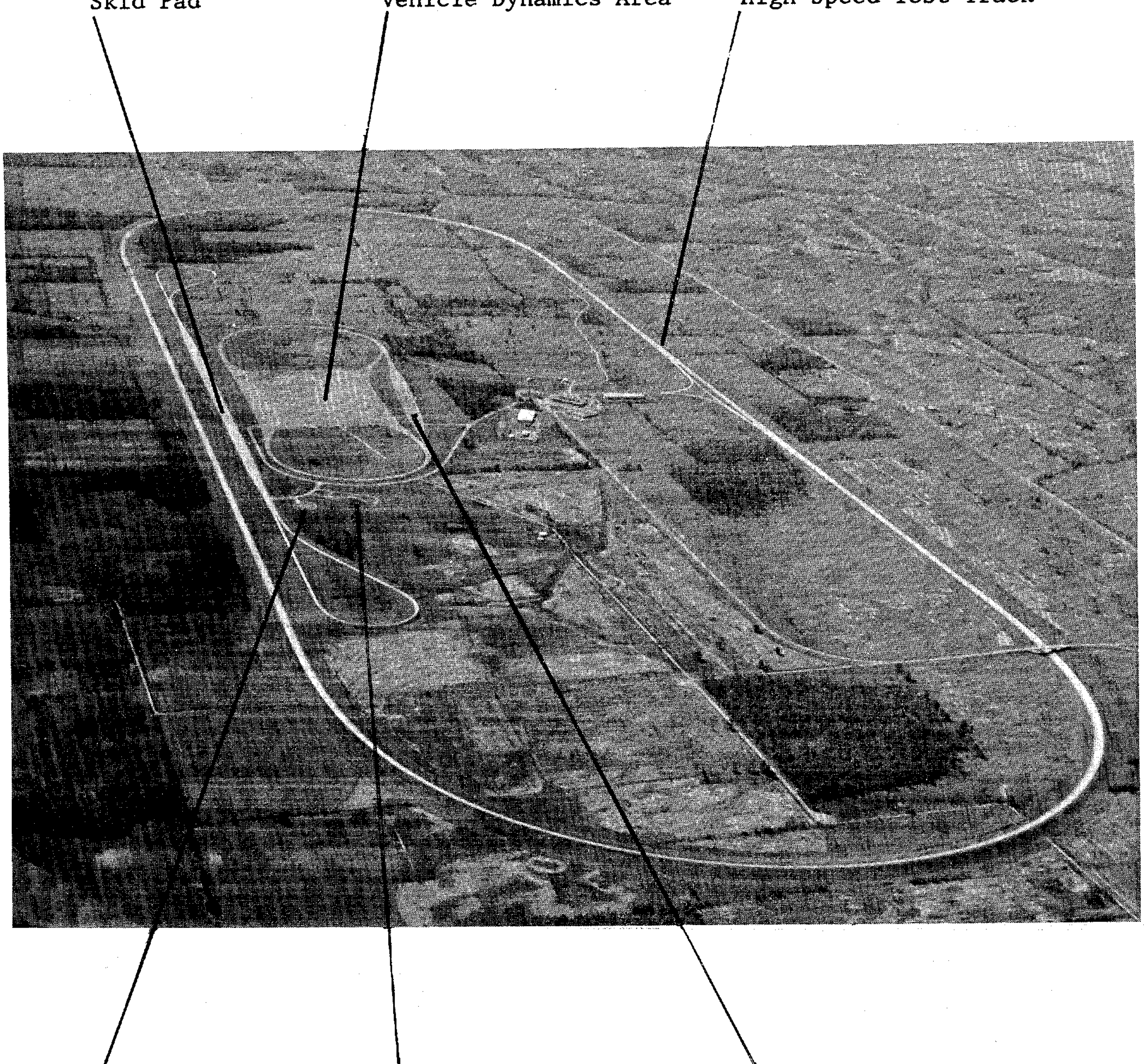


FIGURE 1 -- Aerial View of TRC Facilities

The road transducer plate (RTP) facility was used to measure front/rear brake balance during the axle lockup sequence of the FMVSS 135 Notice 4 procedure and also before and after the brake distribution procedure described in Section 5. A close up view of the facility is shown in Figure 2. The RTP consists of four plates flush with the surface leading up to it. Force transducers attached to the structure of the plates below the surface measure the braking forces as the vehicle passes over the plates. This information is collected and analysed by a computer inside the building. A number of snubs are made at various deceleration levels and at the conclusion of the test, plots showing the percent rear braking versus deceleration and braking efficiency versus peak mu are produced.

The basic design of the RTP facility was supplied by the General Motors Corporation. A complete description of the GM facility can be found in Reference 6. The TRC facility is essentially the same as the GM facility with two notable exceptions of a building over the pads (included at GM and not at TRC) and different computer systems.

The 7-1/2 mile High Speed Track was used for maximum speed determinations, burnishes, and the fade and recovery tests. The static parking brake tests were conducted on the 20% slope of the parking brake hill.

2.2 Test Vehicles

A list of the test vehicles used is given in Table 1. These vehicles were selected to cover the range of loads up to 8500 lb GVWR with different types of brake systems and drive configurations. The Dodge Caravan, the Chevrolet Astro and the 1988 Chevrolet C-1500 were rented from local rental companies or dealerships. The two Toyota vehicles, the Ford E-250, the Nissan Truck, the Chevrolet S-10 and the Jeep Cherokee were borrowed from the manufacturers. The Ford F-150 and the Dodge Dakota were borrowed from other NHTSA programs. Finally, the Ford F-150 4X4 and the Ford Ranger were rented from individuals. In all cases, new brake parts were installed on the

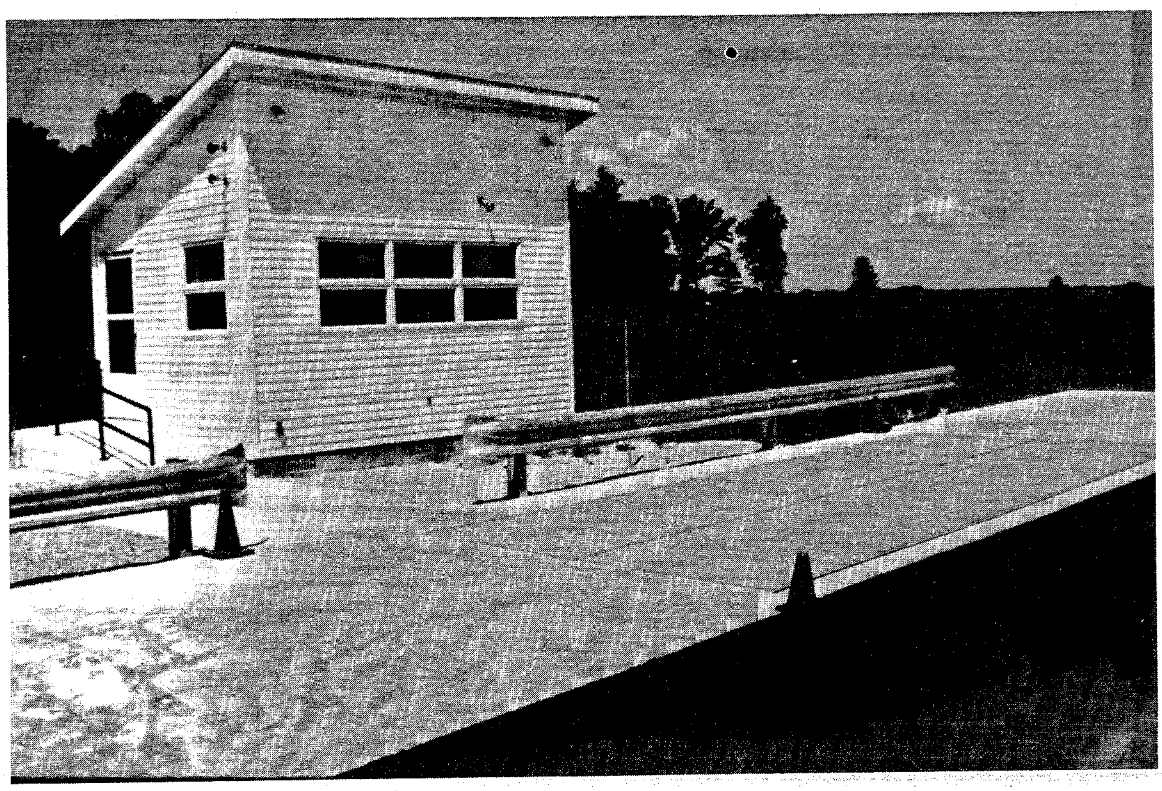


FIGURE 2 -- Close Up View of Road Transducer Plate

TABLE 1 -- Test Vehicles

No.	Vehicle Type	Wheelbase (mm)	Drive	Brake System	GVWR (kg)	Vehicle
1	Van	2845	FWD	V.P.	2200	Dodge Caravan
2	Van	2243	RWD	V.P.	2243	Toyota Van
3	Van	3340	RWD	C	2378	Chevrolet Astro
4	Van	3505	RWD	V.P.	3265	Ford E-250
5	Small Pickup	2949	RWD	V.P.	1996	Nissan Truck
6	Large Pickup	3124	4WD	C	2314	Chevrolet S-10
7	Small Pickup	2743	RWD	C	1763	Ford Ranger
8	Large Pickup	2967	RWD	AL	2177	Ford F-150
9	Large Pickup	3353	RWD	AL	2540	Chevrolet C-1500
10	Large Pickup	3391	4WD	C	2741	Ford F-150 4X4
11	Small Pickup	2845	RWD	V.P.	1865	Dodge Dakota
12	Multipurpose	2624	4WD	V.P.	2304	Toyota 4-Runner
13	Multipurpose	2576	4WD	C	1960	Jeep Cherokee

V.P. = Variable Proportioning, C = Conventional, AL = Antilock vehicles prior to the FMVSS 135 Notice 4 tests and new parts were again installed prior to the brake balance tests. (The 1988 Chevrolet C-1500 pickup was a new vehicle and was trailered from the dealers lot to VRTC and so new parts were not installed on this vehicle prior to the FMVSS test.) In many cases, the brake parts were supplied or purchased directly from the manufacturer. For the remainder of the vehicles, the parts were purchased from local dealerships. For those vehicles which had tires with more than 5000 miles on the tires, new tires were also installed prior to the testing. Each of the vehicles was checked and, where necessary, reset to factory timing and idle rpm settings. On those vehicles equipped with variable proportioning valves, the valves were checked to be sure that they were set according to the manufacturers specifications. The valve on one of the vehicles was incorrectly set and was reset according to the service manual.

The two vehicles equipped with antilock (Ford F-150 and Chevrolet C-1500) use a system which senses the drive shaft speed and only controls the rear wheels. Both vehicles use a system supplied by the same manufacturer, however, the plumbing arrangements of the two vehicles are slightly different.

2.3 Instrumentation

The test vehicles were equipped with instrumentation to measure the following variables:

a) vehicles speed
b) stopping distance
c) deceleration
d) service brake pedal force
e) parking brake pedal or lever force
f) brake lining temperature
g) wheel lockup
h) time between two selected speeds
i) brake line pressure

Speed and stopping distance were measured using a commercially available fifth wheel system. The fifth wheel drives a magnetic pick-up and pulses from this pick-up are fed into two digital meters. Electronics in the meters sum the pulses from the wheel to indicate distance traveled and differentiate this distance traveled continuously with respect to time to indicate speed. The system has a 12 volt trigger circuit to initiate distance measuring and "memorize" speed at the instant of trigger. The trigger circuit is connected to the 12 volt stoplight circuit on the vehicle and the brake pedal is adjusted so that a slight movement (1/8 inch or less) of the pedal provides the trigger signal. During stopping distance tests, the driver simply brings the vehicle up to the desired test speed by watching the speed meter and then applies the brake. When the vehicle reaches a stop, the distance meter indicates the stopping distance (to the nearest 0.1 ft.) and the velocity meter indicates the speed (to the nearest 0.1 mph) at which the brakes were initially applied. The system does not measure suspension rock-back at the end of a stop (it stops counting the first time the wheel reaches zero speed) and it does not stop counting distance if the brake pedal is fully released by the driver during modulation of pedal force while the vehicle is moving.

Calibration of the stopping distance system was accomplished by running the vehicle over a 1000 foot measured course. Fifth wheel tire pressure was adjusted so that distance indicated agreed with the measured course. Calibration of speed was performed on a motor driven calibration stand. Overall accuracy of the system was determined to be better than ±0.2 percent of indicated reading for distance and ±0.2 mph for speed.

In addition to the triggered or "memorizing" velocity meter, a second untriggered meter (in parallel with the triggered meter) was used with its output driving a digital to analog converter to provide a reference signal for the lockup detector system.

Vehicle deceleration measurements were made using a servo accelerometer. The output signal of the accelerometer was sent to a meter on the dash for the driver to utilize during constant deceleration tests and to a strip chart recorder. The deceleration readings are slightly higher than the actual deceleration due to the pitch of the vehicle. This error is equal to the sine of the pitch angle (which is generally small) times the acceleration due to gravity. This error is typically in the order of 5 percent.

The service brake pedal force was measured by a strain gage load cell mounted to the brake pedal. The output signal was sent to a meter on the dash and to a strip chart recorder. The same type of load cell was used on pedal actuated parking brakes for the parking brake tests. For lever type parking brakes, a strain gaged load cell was fasteded to the hand lever at the center of the hand grip area with a hose clamp. Pedal and lever load cells were dead weight calibrated and measurements were accurate to within ±2 lbs.

Thermocouples, fabricated from 20 gauge iron-constantan wire, were utilized to measure brake lining temperatures. "Quick tip" crimp-on connectors were used to form the thermocouple junction. These thermocouple tips, which, when crimped, form a hexagon shape, were installed by drilling an undersized hole in the lining and then driving the tip to a depth of 0.040 inches. Thermocouples (one per brake) were installed in the most heavily loaded shoe or pad in the brake as per the proposed procedure.

Each vehicle was equipped with a single channel high impedance digital thermocouple readout and a multi-position thermocouple selector switch to which all of the thermocouples were connected. By rotating the switch, the driver could observe the lining temperature of each brake. During the fade and recovery portion of the test, a temperature recorder was also used to provide a continuous reading of the brake temperatures. Overall system accuracy was determined to be better than ±5 degrees Fahrenheit.

The system used for determining wheel lockup consisted of dc tachometer generators installed at each wheel and a "lockup box" with electronic circuitry to which the signal from the wheel tachometers were connected. Also connected to the circuit was an analog signal from a digital to analog converter "reading" the vehicle velocity meter. An analog comparator circuit in the box compares "wheel velocity", which is equal to the wheel's rotation rate multiplied by the rolling radius of the wheel, to the vehicle's velocity as measured by the fifth wheel. Whenever the "wheel velocity" falls below five percent of the vehicle velocity (i.e., whenever the wheel slip exceeps 95 percent), the wheel is considered to have locked up and the comparator triggers additional circuits. A bulb is illuminated on the front panel of the box indicating that the wheel has locked during the stop. The "lockup box" can also be set up to output to a recorder a discrete voltage for each wheel to show when it is locked. The system is designed to disregard lockup at vehicle speeds below 15 km/h.

Although the exact definition of wheel lockup requires that the wheel be at 100 percent slip, the lockup detectors use the 95 percent slip criteria because it greatly simplifies the electronics by eliminating the need to know when wheel velocity is exactly at zero. The error introduced by using this criteria is very small because any wheel that reached 95 percent slip will continue to 100 percent slip almost instantaneously since it is operating in an unstable region of the tire-road coefficient of friction curve.

The method for determining the time between two speeds used the "lockup box" which also has circuitry to compare the vehicle speed to preset values. These values are set by the driver prior to the test, then the driver exceeds the higher of the two speeds and as the vehicle decelerates through the higher speed the timer starts counting. When the speed goes below the lower set speed, the timer stops and an audible alarm alerts the driver that he is below that speed. The "lockup box" also incorporates an external timer to alert the driver at set intervals which is used during the fade where stops are made every 40 seconds.

The brake line pressures were measured by installing T's in the brake line with a strain gage type pressure transducer in one leg of the T. The pressure transducers were dead weight calibrated for accuracy and a shunt resistor was installed for periodic checks on the system calibration.

For the FMVSS tests, a two channel strip chart recorder was used in each vehicle to record deceleration and pedal force (or lever force in parking brake tests) during the stopping distance tests and the fade tests. During the axle lock sequence tests, vehicle speed was recorded on one channel and a signal showing wheel lockup (from the "lockup box") was recorded on the other channel. For the brake balance tests, a four channel recorder was used to record pedal force, vehicle speed, and front and rear brake line pressure. Electrical power for the recorders and other 115 vac powered instruments was provided by a dc to ac static inverter powered by the vehicle's electrical system.

3.0 TESTS TO THE FMVSS 135 NOTICE 4

This section of the report describes the testing to the FMVSS 135 Notice 4 procedure. A discussion of the test procedure and the results will be given and also comparisons made to a 19 passenger car sample tested to the same procedure.

3.1 Test Procedure - FMVSS 135 Notice 4 Tests

These tests were conducted in accordance with the FMVSS 135 Notice 4 procedure. A summary of this procedure is given in Table 2 with a more detailed description of the procedure given in Appendix A. In addition to the FMVSS 135 tests, an RTP test was run after each of the axle lock sequences for eight of the vehicles and for two more, the RTP was run after one of the axle lock sequences to compare the results. (The RTP was not fully operational when this program was begun and thus was not used on all vehicles.) In order to have additional data on the vehicles and the test procedure, a post fade

TABLE 2 -- FMVSS 135 Notice 4 Test Schedule

1. Load Vehicle to GVWR

2. Burnish
   a. 80 km/h, 3 m/s^2 in gear - 200 stops

3. Service Brake Effectiveness at Full Load
   a. Low Coefficient, 50 km/h in neutral - 6 stops
   b. Axle lockup sequence, 20 SN, 65 km/h in neutral
   c. Axle lockup sequence, 50 SN, 65 km/h in neutral
   d. 100 km/h in neutral - 6 stops
   e. 80 % V_{max} in gear - 6 stops
   f. 100 km/h engine off in neutral - 6 stops

4. Unload Vehicle

5. Service Brake Effectiveness at Light Load
   a. Low Coefficient, 50 km/h in neutral - 6 stops
   b. Axle lockup sequence, 20 SN, 65 km/h in neutral
   c. Axle lockup sequence, 50 SN, 65 km/h in neutral
   d. 100 km/h in neutral - 6 stops
   e. 80 % V_{max} in gear - 6 stops

6. Partial System Tests at Light Load
   a. Anti-lock failed, 100 km/h in neutral - 6 stops
   b. Variable prop failed, 100 km/h in neutral - 6 stops
   c. Circuit 1 failed, 100 km/h in neutral - 4 stops
   d. Circuit 2 failed, 100 km/h in neutral - 4 stops

7. Load Vehicle to GVWR

8. Partial System Tests at Full Load
   a. Circuit 2 failed, 100 km/h in neutral - 4 stops
   b. Circuit 1 failed, 100 km/h in neutral - 4 stops
   c. Anti-lock failed, 100 km/h in neutral - 6 stops
   d. Variable prop failed, 100 km/h in neutral - 6 stops
   e. Power assist failed, 100 km/h in neutral - 6 stops

9. Parking Brake Tests Loaded
   a. Static 20 % grade, uphill/downhill in neutral
   b. Dynamic, 60 km/h in neutral - 2 stops

10. Fade and Recovery Loaded
    a. Heating, slower of 120 km/h or 80 % V_{max} to 1/2 initial speed, 3 m/s^2, 40 second interval - 15 snubs
    b. Hot performance, 100 km/h in neutral - 2 stops
    c. Recovery, 50 km/h in gear 3 m/s^2 - 4 stops
    d. Recovery performance, 100 km/h in neutral - 2 stops

effectiveness test consisting of 6 best effort stops from 100 km/h was run. All of the vehicles were tested by the same driver and this driver also tested the 19 passenger cars discussed in Reference 5.

3.2 Test Results - FMVSS 135 Notice 4 Tests

The test results for the FMVSS 135 Notice 4 tests will be shown graphically. A summary data sheet for each of the vehicles is given in Appendix B along with a vehicle information sheet, pictures of the vehicles and of any special equipment on the vehicle. Numbers on the graphs shown in this section of the report correspond to the vehicle numbers shown in Table 1. The results are also given in tabular form in Appendix C. At the end of this section, comparisons of the results of these tests will be made to the results of the 19 passenger car sample discussed in Reference 5.

The low coefficient stopping distance test is run on a 20 SN surface from 50 km/h. The results from the laden and unladen tests are shown in Figure 3. The average for the 13 vehicles in the laden condition is 28.3 m with a range from 24 m to 36 m. In the unladen condition the average is 24.9 m and a range from 22 m to 32 m.

The axle lock sequence tests are run on a 20 SN surface and a 50 SN surface in both the laden and unladen conditions. The tests are run by making stops from 65 km/h with constant pedal force. The pedal force is incremented until only one axle locks. For eight of the vehicles (Dodge Caravan, Chevrolet Astro, Nissan Truck, Ford Ranger, Ford F-150 4X4, Dodge Dakota, Toyota 4-Runner and Jeep Cherokee), an RTP test was run immediately after each of the axle lock sequences. The Toyota Van was run on the RTP only after the unladen axle lock sequence and the Chevrolet C-1500 was run on the RTP only after the laden sequence. Plots showing the results of these RTP tests are given in Appendix D. Table 3 shows the results of the axle lock sequence tests and the predictions made from the RTP tests (where available) which were run immediately after the axle lock sequence. The RTP graphs in Appendix D show the results in terms of peak tire to

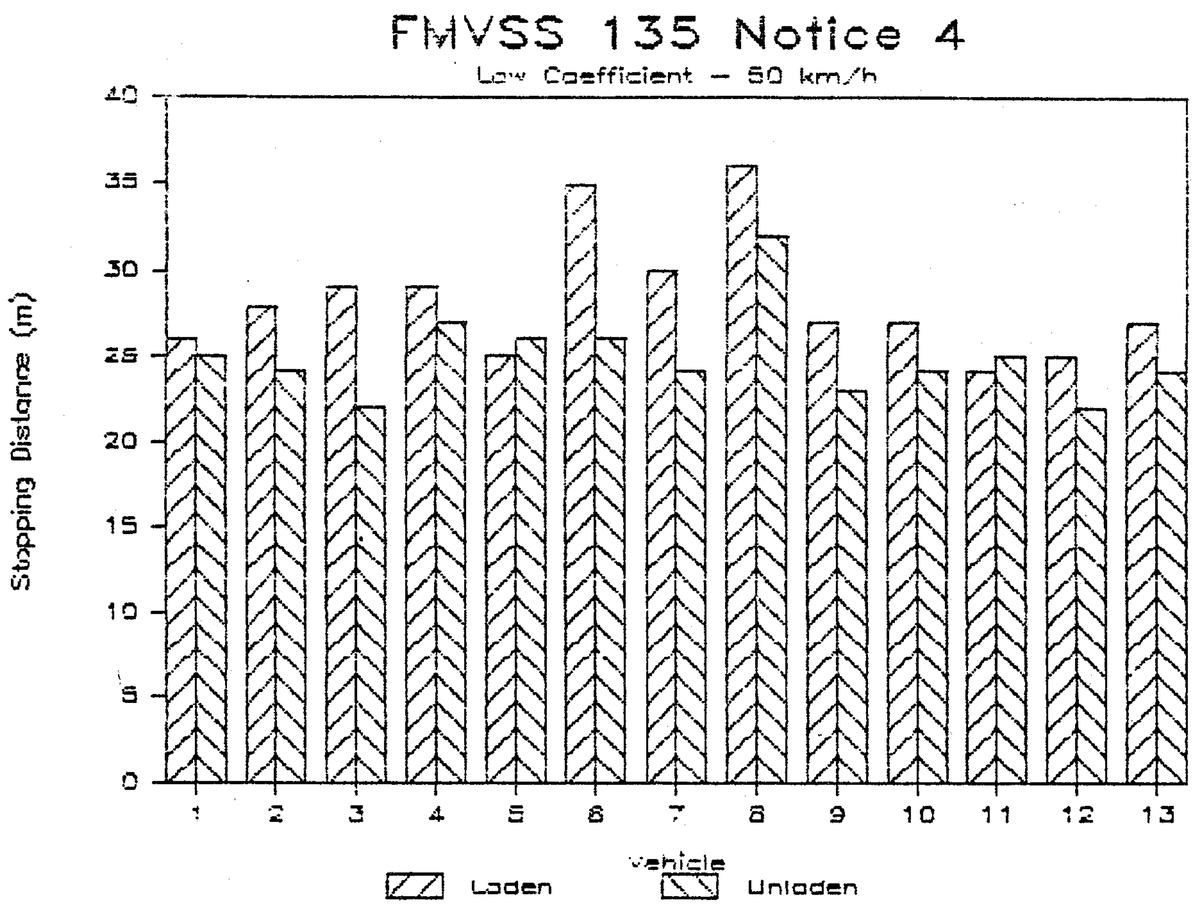

FMVSS 135 Notice 4
Low Coefficient – 50 km/h
Stopping Distance (m)
0
5
10
15
20
25
30
35
40
1
2
3
4
5
6
7
8
9
10
11
12
13
Vehicle
Laden
Unladen

FIGURE 3

TABLE 3 -- Axle Lock Sequence Results

	Axle Lock Sequence				RTP Prediction			
	Laden		Unladen		Laden		Unladen	
	20SN	50SN	20SN	50SN	20SN	50SN	20SN	50SN
Dodge Caravan	F	F	F	F	F	F	F	F
Toyota Van	F	F	F	F	NA	NA	F	?
Chevrolet Astro	F	F	F	F	F	F	F	F
Ford E-250	F	R	F	F	NA	NA	NA	NA
Nissan Truck	F	F	F	F	F	F	F	F
Chevrolet S-10	F	F	F	F	NA	NA	NA	NA
Ford Ranger	F	R	F	R	F	R	?	R
Ford F-150	F	F	F	F	NA	NA	NA	NA
Chevrolet C-1500	F	F	F	F	F	F	NA	NA
Ford F-150 4X4	F	F	F	F	F	F	F	?
Dodge Dakota	F	F	F	F	F	F	F	F
Toyota 4-Runner	F	F	F	F	F	F	F	F
Jeep Cherokee	F	F	F	F	F	F	F	F

road coefficient of friction and not skid number. In making these predictions, a peak mu value in the range of 0.4 to 0.6 was used for the 20 SN surface and a peak mu value in the range of 0.8 to 0.9 was used for the 50 SN surface. Note that the table has a question mark for the Ford Ranger unladen on the 20 SN surface, and the Toyota Van and Ford F-150 4X4 in the unladen condition on the 50 SN surface. This means that a precise prediction of lockup sequence could not be made due to lack of sufficient tire data and/or RTP data. For the Ford Ranger, the plots from the RTP tests indicate a change from rear bias to front bias at a peak mu of approximately 0.25 and then back to front biased at a peak mu of approximately 0.45. Without further data on the tires, it is unknown what peak mu value would be appropriate for the 20 SN surface. Additional RTP data would also be necessary to more accurately define the mu values where the vehicle changes from front to rear or rear to front brake bias. In the case of the Toyota, the test was only run at decelerations high enough to make predictions on a surface with a peak mu of 0.45. For the Ford F-150 4X4, the predicted brake balance changes from front to rear biased on a surface having a peak mu value of approximately 0.7. As in the case with the Ranger, additional data on the vehicle tires would be necessary to know if the 50 SN surface would have a peak mu value greater or less than 0.7 and more RTP data to know the exact crossover point, so no prediction could be made. For the remainder of the cases where RTP data was available, the predictions and the test results agree. All of the 13 vehicles locked the front axle first on the 20 SN surface and only two of the vehicles (Ford E-250 laden and the Ford Ranger laden and unladen) had the rear axle lock first on the 50 SN surface.

The full system 100 km/h test results both laden and unladen are shown in Figure 4. The average, minimum and maximum distances for the laden tests were 59.5 m, 50 m and 66 m respecitvely. For the unladen tests, the average was 54.8 m with a range of 51 m to 60 m.

Full system tests are also run at 80 percent of the maximum speed of the vehicle. For these vehicles, the maximum speed was determined by accelerating the vehicle to its maximum speed twice in

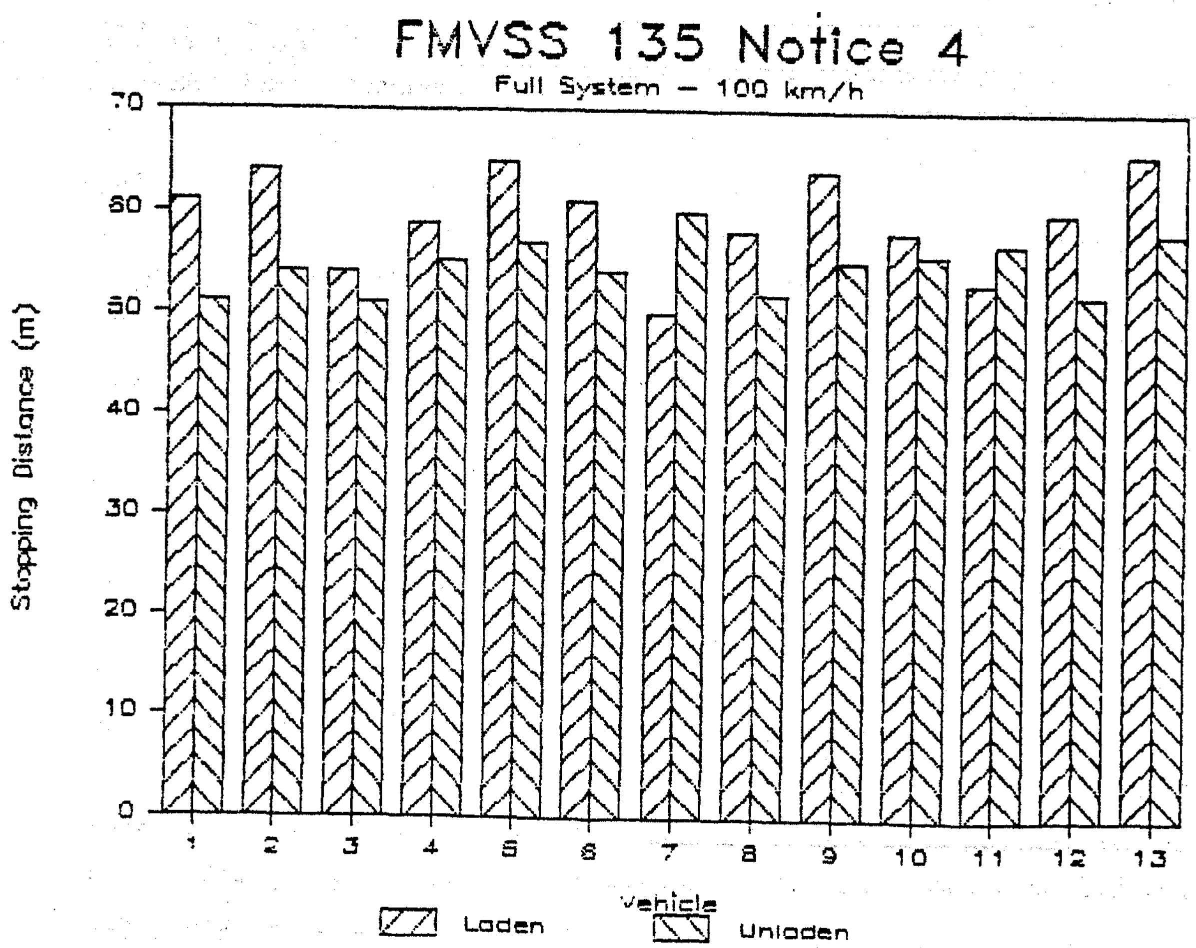

FMVSS 135 Notice 4
Full System — 100 km/h
Stopping Distance (m)
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
9
10
11
12
13
Vehicle
Laden
Unladen

FIGURE 4

each direction on the high speed track. The average of the four speeds was used for the vehicle maximum speed. The results of the tests at 80 percent of V_{max} are shown in Figure 5, showing the best stop distance as a function of the test speed. To establish requirements for passenger cars on this test, FMVSS 135 Notice 4 sets a minimum deceleration level the vehicle must meet. The vehicle deceleration is calculated using the stopping distance, the initial speed and an assumed system reaction time of 0.25 seconds. Using this same system reaction time, vehicle decelerations were calculated and are shown in bargraph form in Figure 6. The average laden deceleration level was 7.44 m/s^2 with a range from 6.27 m/s^2 to 8.67 m/s^2. For the unladen tests, the average deceleration was 8.22 m/s^2 and ranged from 7.45 m/s^2 to 8.94 m/s^2.

The full system 100 km/h tests with the engine off results are shown in Figure 7. This test is only run in the laden condition. Average, minimum and maximum values were 58.3 m, 46 m and 69 m respectively.

The failed system tests are all run at 100 km/h. The results for the laden circuit failure tests are shown in Figure 8. All but one of the vehicles (Dodge Caravan) have front/rear plumbing splits. The letters above the bars in this and the next graph indicate the axle on which the brakes were failed. For this set of tests, the overall average (i.e. the average for all of the vehicles with both failures together) was 109.8 m and the range was 70 m to 198 m. For the unladen condition, the results are shown in Figure 9. Again overall values were used giving an average of 107.5 m and a range of 59 m to 201 m. In both of these tests, vehicle number 8 (Ford F-150) with the front brakes failed had the longest stopping distance. This vehicle had a rear wheel antilock system which allowed full pedal effort to be applied without wheel lockup during the test with the front brakes failed. Vheicle 9 (Chevrolet C-1500) had the same rear wheel antilock system using a different plumbing arrangement and had shorter stopping distances during the failed front brakes tests. It is unclear why the performance of these two vehicles are different.

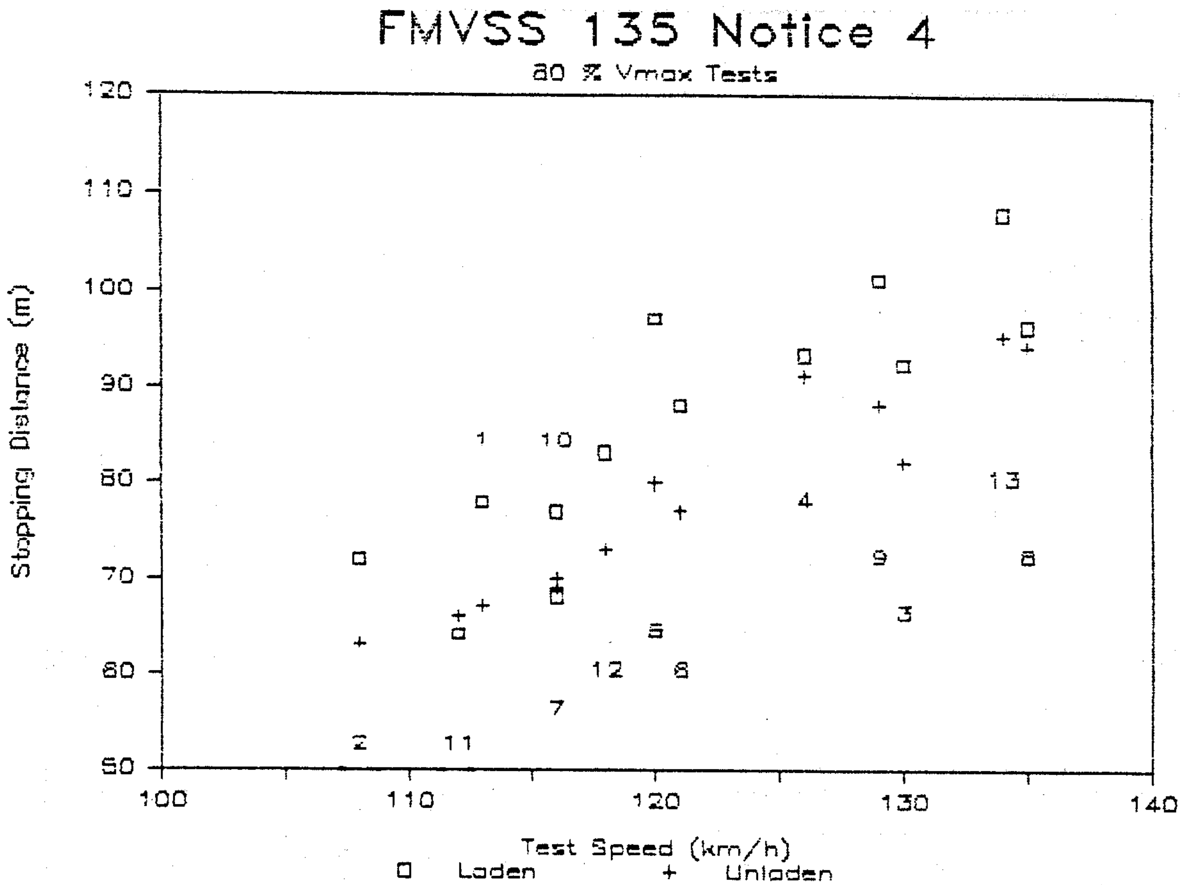


FIGURE 5

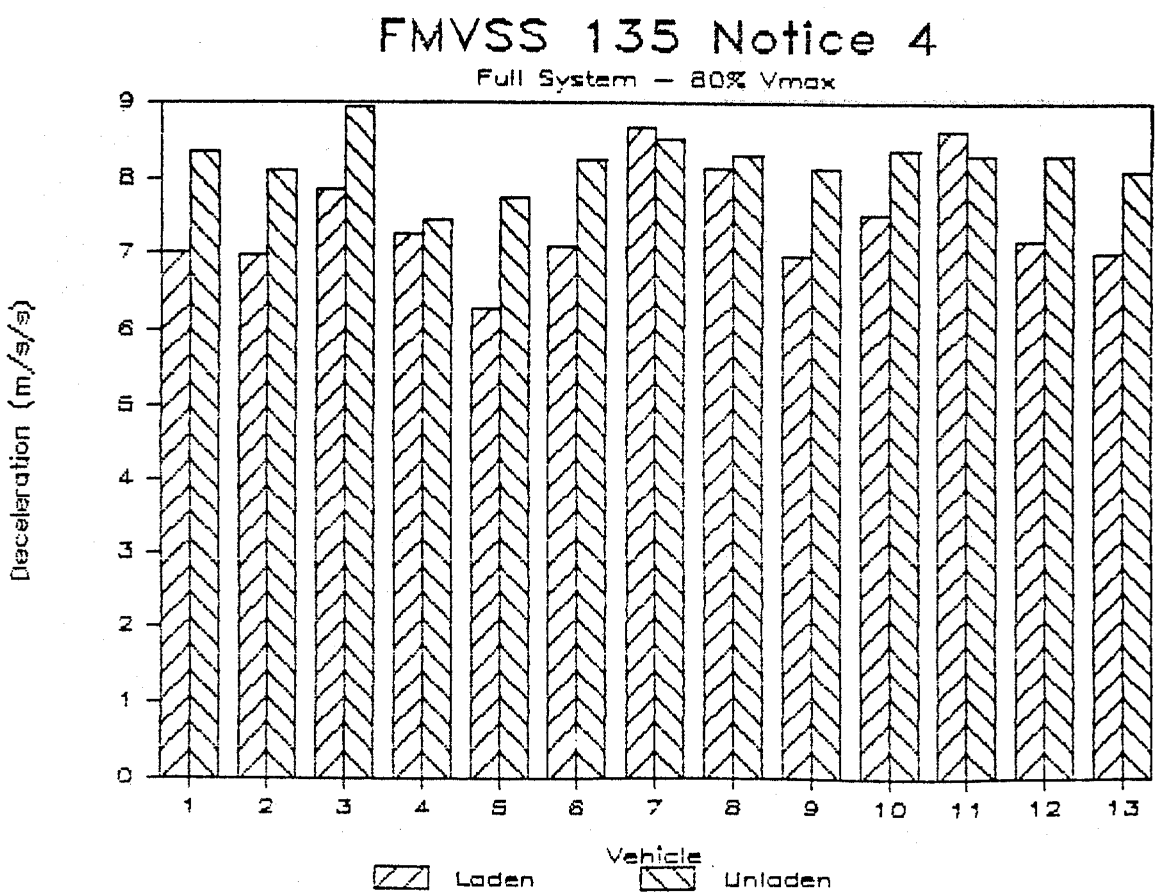


FIGURE 6

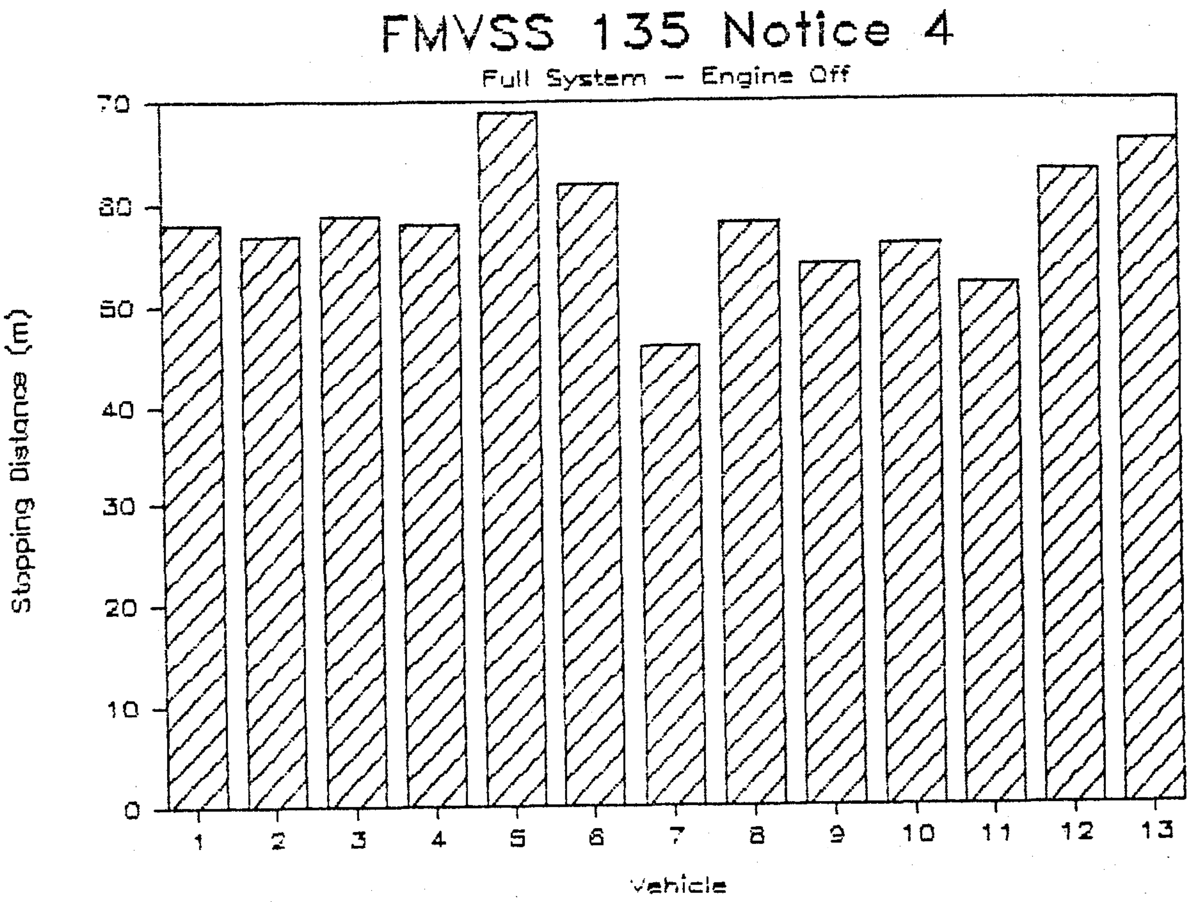

FMVSS 135 Notice 4
Full System — Engine Off
Stopping Distance (m)
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
9
10
11
12
13
Vehicle

FIGURE 7

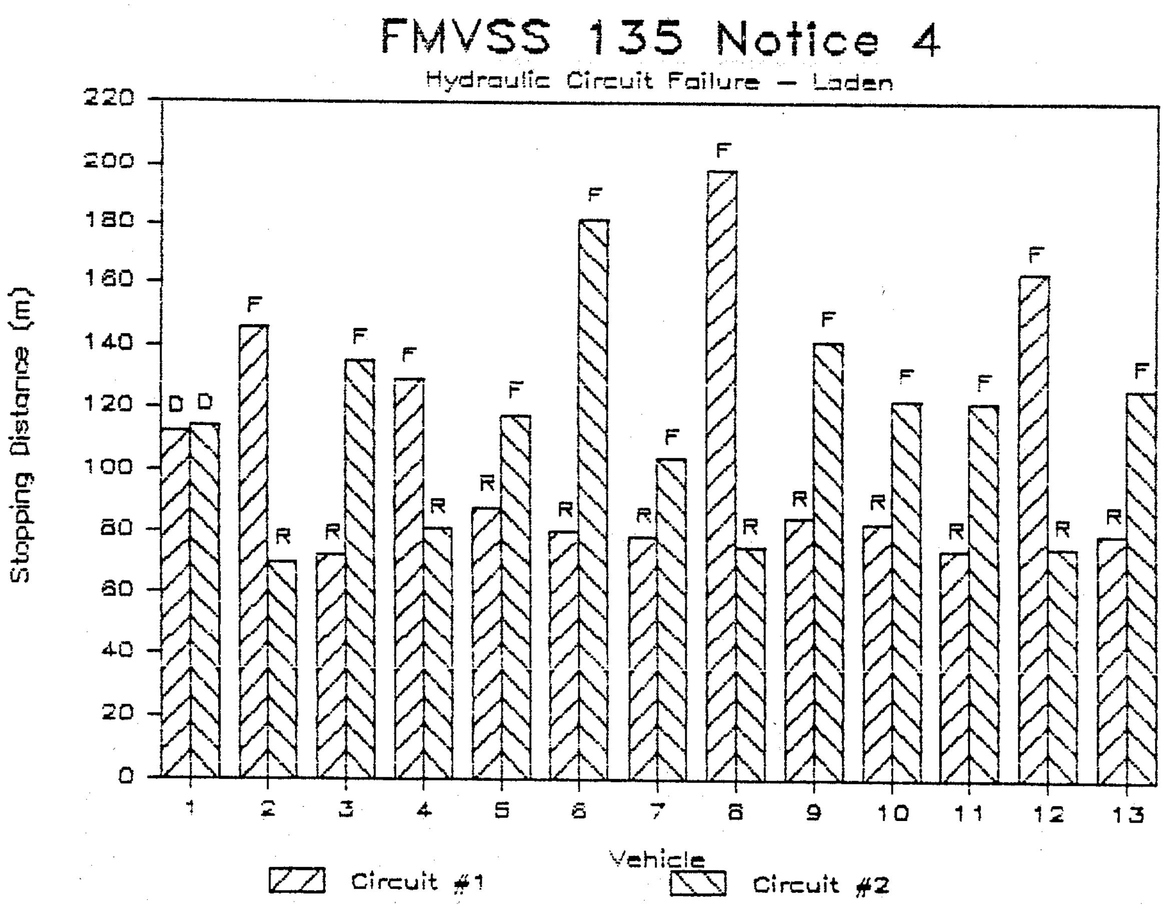


FIGURE 8

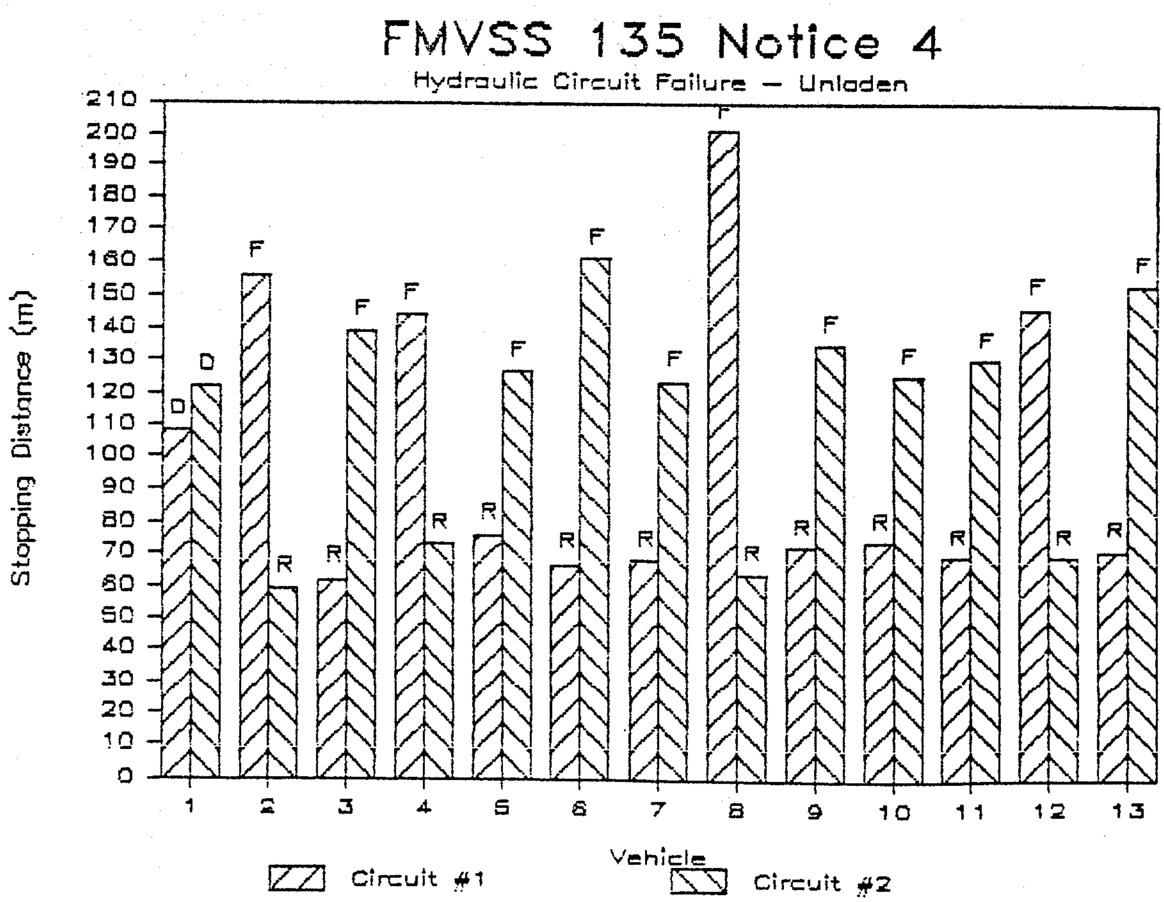


FIGURE 9

The failed power assist test results are shown in Figure 10. This test is only run in the laden condition. The average for the 13 vehicles was 125.1 m with a range of 62 m to 180 m.

For the vehicles which have variable proportioning systems or antilock systems, the stopping distance performance with these systems failed was measured. The results of these tests are shown in Table 4. The antilock systems were failed by disconnecting the power to the unit. On the Ford F-150, however, the incorrect wire was disconnected and due to the smooth operation of this antilock system, the driver was unaware that the antilock was still operational during the "failed antilock" tests. This problem was not detected until all of the testing on this vehicle had been completed. Stopping distance tests were repeated in both load conditions with the antilock system operational and with it failed. The percent increase in stopping distance with the system failed was calculated for both load conditions. From these percentages and the FMVSS 135 Notice 4 full system stopping distances, the failed system stopping distances shown in Table 4 were calculated. Table 4 shows an improvement in stopping distance (negative increase) for the C-1500 with the antilock failed in the laden condition. In the laden condition, this vehicle is front brake biased and so failing the antilock system should not effect the stopping performance. The six percent change in stopping distance is probably due to a change in the brake effectiveness from the time the full system tests were run to the time the failed system tests were run and test to test variability.

Of the vehicles equipped with variable proportioning, all except the Nissan truck had height sensing valves. These valves use a linkage which senses the distance between the bed and the rear axle. As the vehicle is loaded, this distance decreases and the proportioning valve decreases the amount of rear brake proportioning. The Ford E-250 had a two stage valve which set the proportioning to one of two levels. The other height sensing valves were continuously variable. Where possible, the valves were failed to simulate the worst case condition. This means that when the vehicle was fully loaded, the

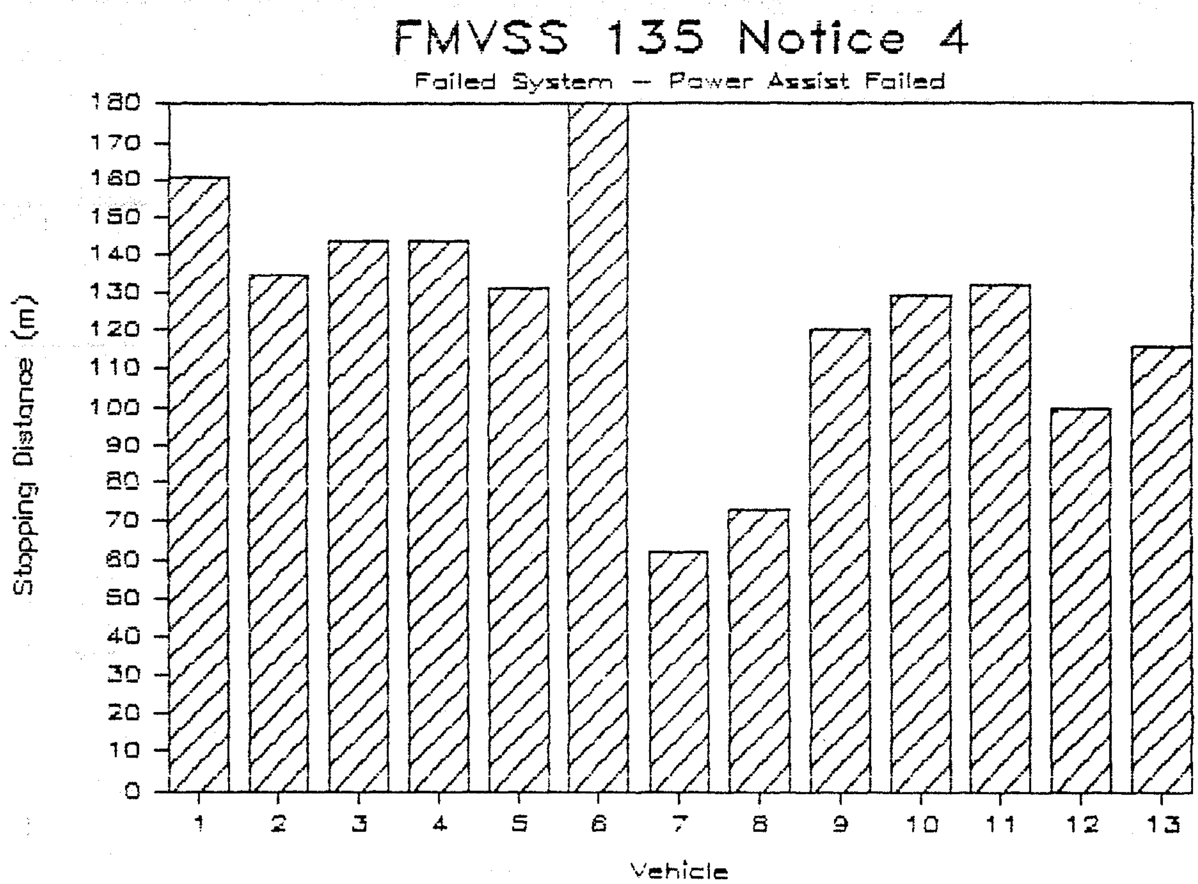

FMVSS 135 Notice 4
Failed System — Power Assist Failed
Stopping Distance (m)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
1
2
3
4
5
6
7
8
9
10
11
12
13
Vehicle

FIGURE 10

TABLE 4 -- Failed Variable Prop and Failed Antilock Results

		Laden			Unladen		
		System		In-	System		In-
		Full	Failed	crease	Full	Failed	crease
Vehicle	Sys*	(m)	(m)	(%)	(m)	(m)	(%)
Dodge Caravan	VP	61	63	4	51	61	20
Toyota Van	VP	64	57	-11	54	58	7
Ford E-250	VP	59	63	7	55	55	0
Nissan Truck	VP	65	52	-20	57	67	18
Ford F-150	AL	58	59**	1	52	64**	22
Chevrolet C-1500	AL	64	60	-6	55	55	0
Dodge Dakota	VP	53	63	19	57	58	2
Toyota 4-Runner	VP	60	63	5	52	55	7

*System failed: VP = Variable Prop, AL = Antilock

**Stopping distance calculated from later tests valve was failed such that it was in a lightly loaded position and the rear brake pressure was fully proportioned. Conversely, when the vehicle was lightly loaded, the valve was failed to a fully loaded position and the rear brake pressure had little or no proportioning. It was not possible to do this on the Dodge Dakota, however, so the linkage to the valve was simply disconnected, simulating a lightly loaded condition. The Nissan truck had a deceleration sensing valve which changes the proportioning characteristics based on the vehicle deceleration. On this vehicle, the valve was failed by installing plumbing to bypass the valve (i.e. no rear brake pressure proportioning). Table 4 shows that for two of the vehicles with variable proportioning valves, the stopping distance improved when the valve was failed. This is because the valves on these vehicles proportioned the rear brake pressure more than necessary for that load condition, reducing the rear brake output which resulted in longer stopping distances.

The FMVSS 135 Notice 4 specifies two tests for the parking brake system. The first is a static test where the vehicle is parked on a 20 percent grade both facing uphill and downhill and must hold with only 400 or 500 N force on the parking brake control depending on whether the brake is hand or foot applied respectively. For these tests, the vehicles were parked on the hill and the minimum force to hold the vehicle stationary was determined. This minimum force to hold is shown in Figure 11. The letters above the bars in this graph indicate whether the parking brake is hand or foot acctuated. The Ford F-150 4X4 would not hold with only 500 N force, however, this was an older vehicle and while the parking mechanism appeared to work freely, there may have been friction which would not have been present with a new vehicle.

The second parking brake test is the dynamic test where two stops are made from 60 km/h using only the parking brake. The stopping distance for the best of these two stops is shown in Figure 12 and the deceleration at the very end of that stop is shown in Figure 13. The average stopping distance was 66.6 m, ranging from 43 m to

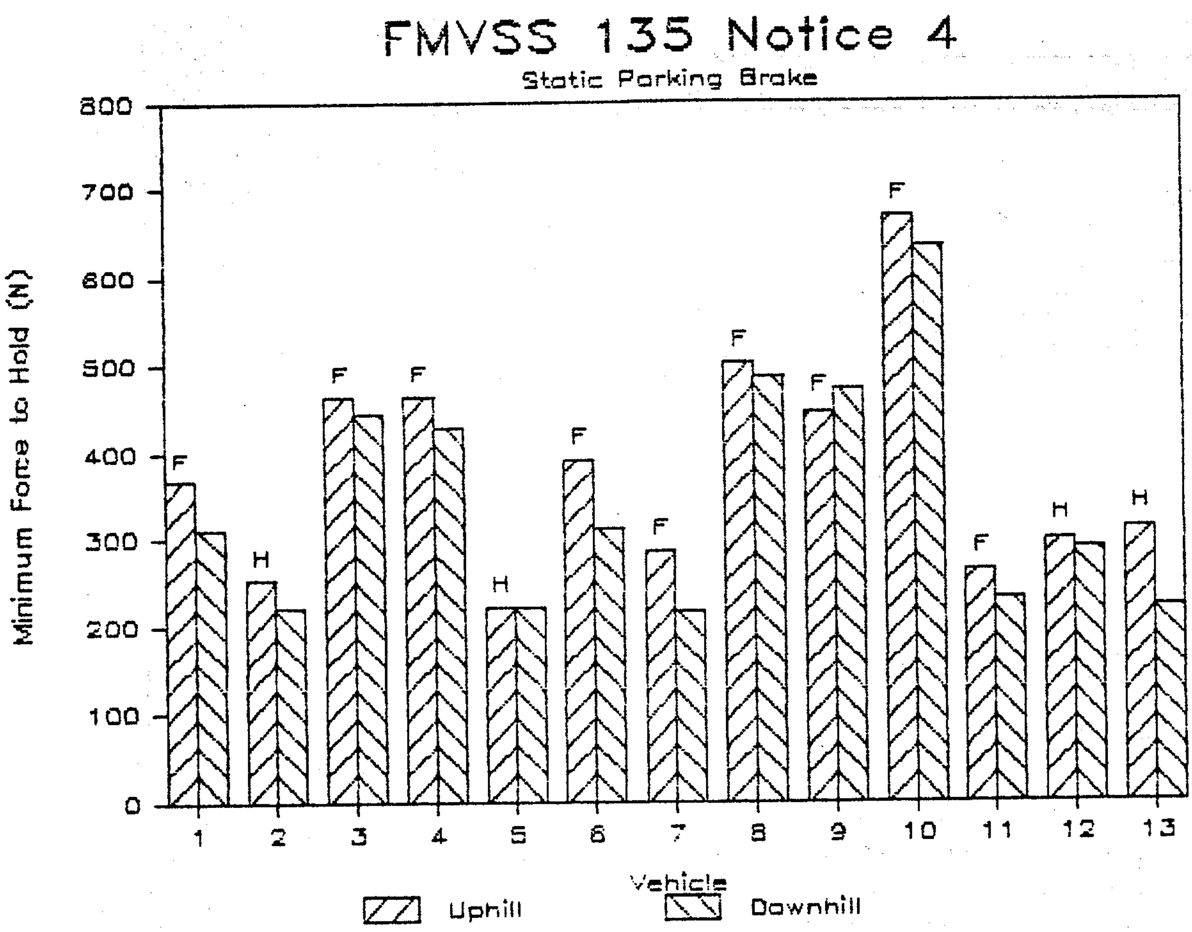

FMVSS 135 Notice 4
Static Parking Brake
Minimum Force to Hold (N)
800
700
600
500
400
300
200
100
0
F
H
F
F
H
F
F
F
F
F
F
H
H
1
2
3
4
5
6
7
8
9
10
11
12
13
Vehicle
Uphill
Downhill

FIGURE 11

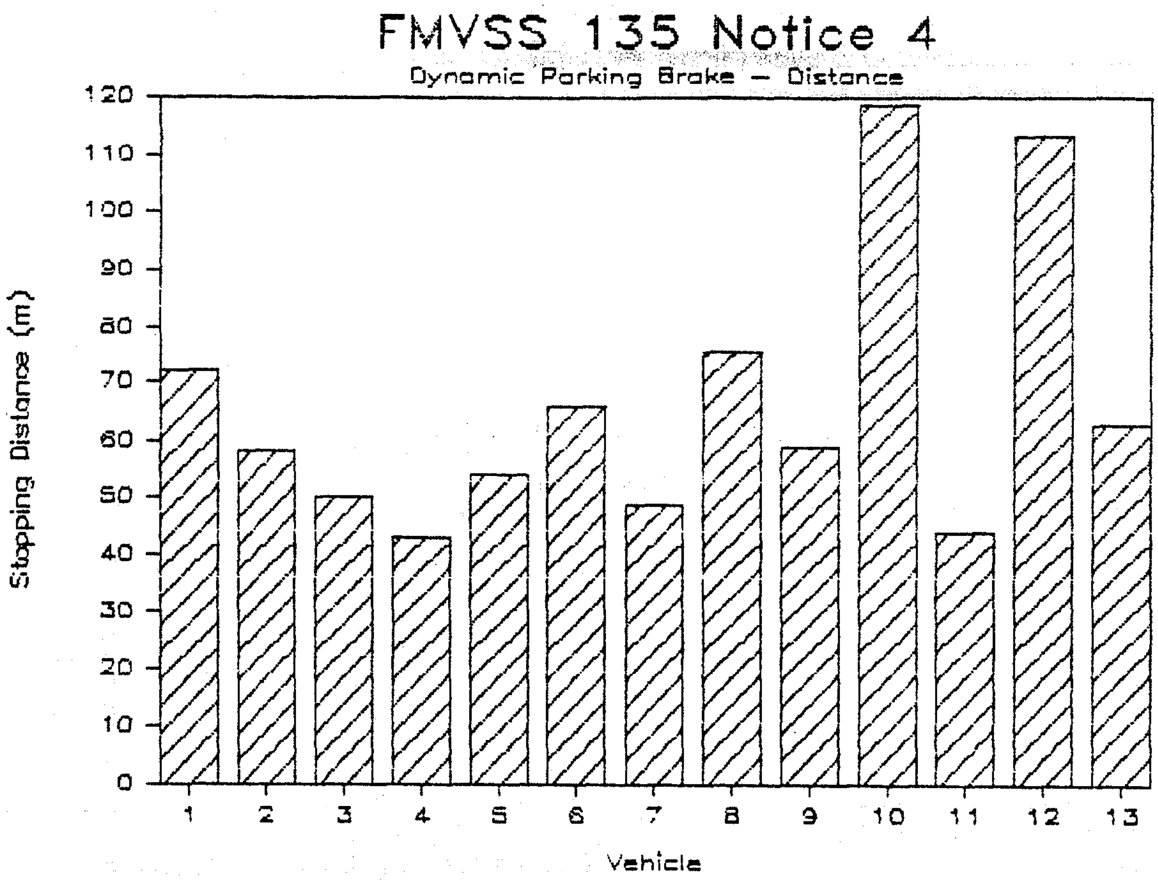


FIGURE 12

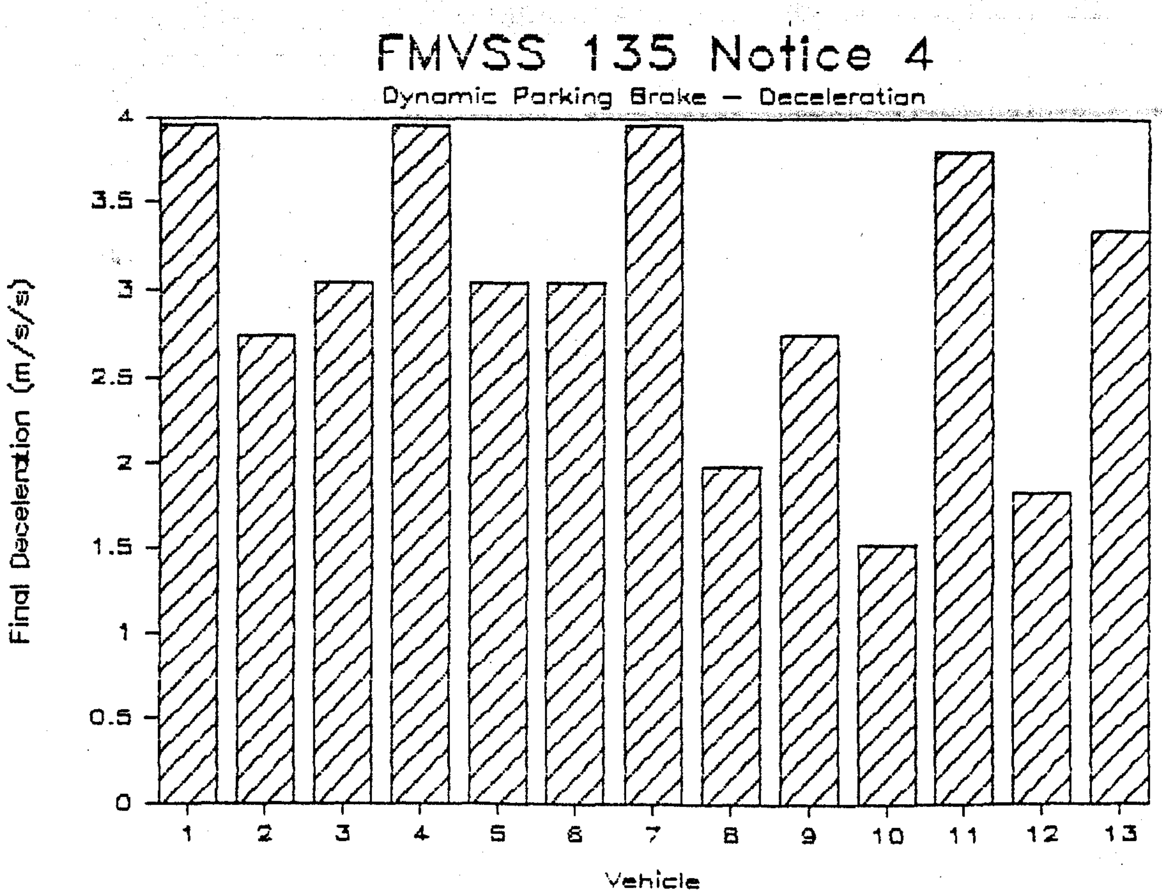


FIGURE 13

119 m. For the final deceleration (deceleration immediately before the vehicle stopped), the average was 3.0 m/s^2 ranging from 1.52 m/s^2 to 3.96 m/s^2.

The fade and recovery sequence consists of heating snubs at 40 second intervals, two 100 km/h hot performance stops, 4 recovery snubs and two 100 km/h recovery performance stops. The best of the two hot performance and recovery performance stops are shown in Figure 14. The average, minimum and maximum distances were 77.3 m, 61 m and 104 m respectively for the hot performance and 67.0 m, 56 m and 77 m respectively for the recovery performance. The ratio of the best cold 100 km/h stopping distance to the hot performance distance and the best cold stop to the recovery performance distance are shown in Figure 15. The average ratio was 0.78 with a range of 0.57 to 0.90 for the hot performance and for the recovery performance the average was 0.89 ranging from 0.78 to 0.97.

The FMVSS 135 Notice 4 test procedure does not include a post fade effectiveness test, however, six 100 km/h best effort stops with the vehicle fully laden were made to have additional data on the vehicles. The results from this test are shown in Figure 16. In general, the post fade distances are about the same as the 100 km/h full system effectiveness with no obvious trends of shorter or longer distances after the fade. The average stopping distance for these stops was 59.7 m ranging from 47 m to 66 m.

In running the thirteen light trucks to the FMVSS 135 Notice 4 test procedure, there were no difficulties associated with testing this type of vehicle to the procedure which would suggest the need to change the procedure.

Nineteen passenger cars were tested to this same procedure and the results are discussed in Reference 5. These 19 cars covered a range of weights and brake configurations so that it was representative of vehicles in the fleet. Comparisons of the results for

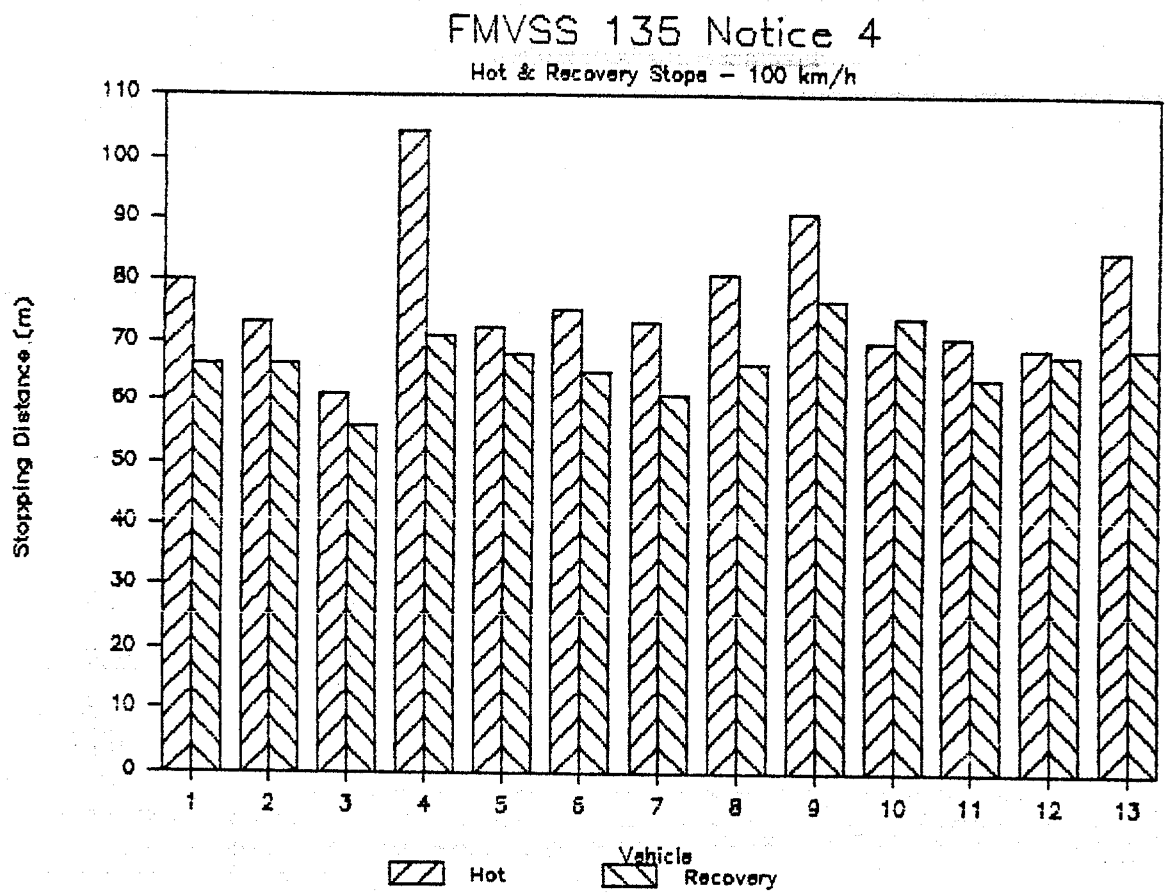


Figure 14

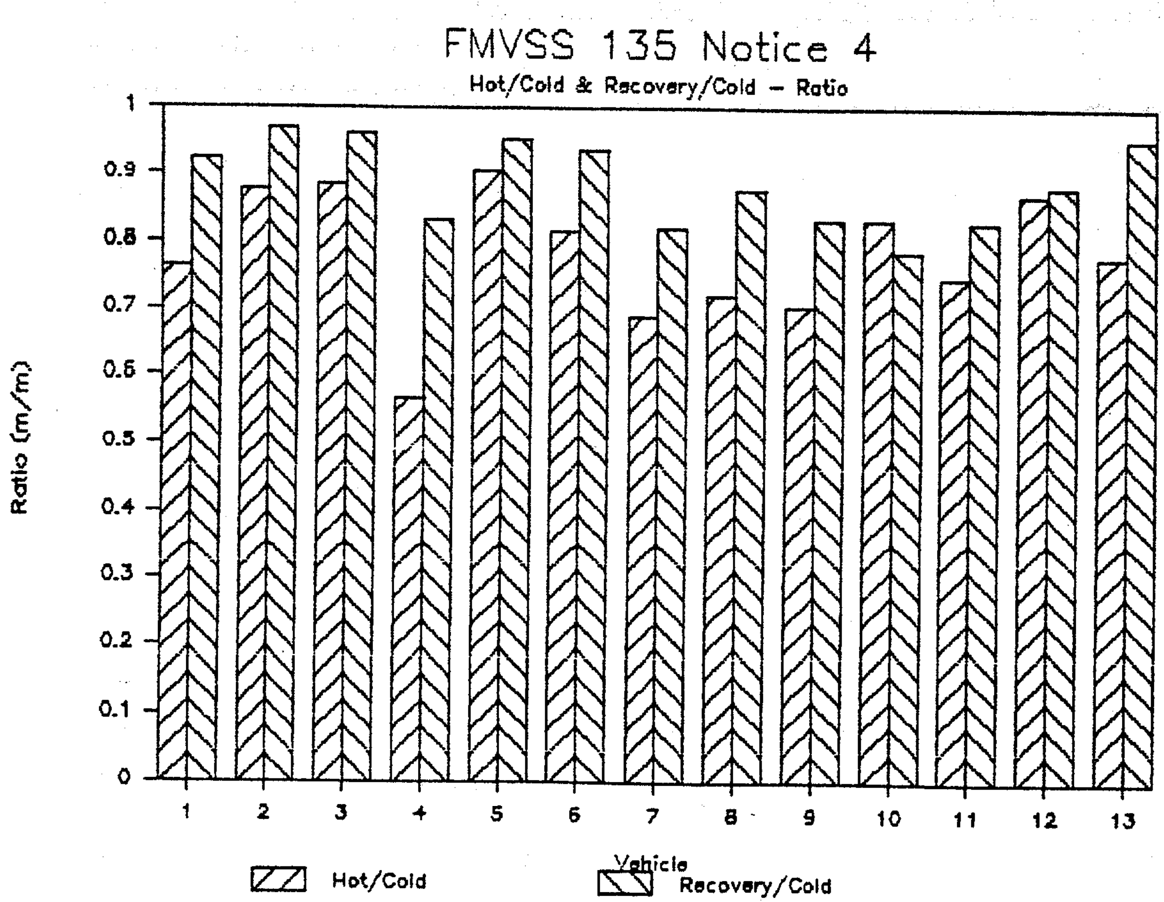
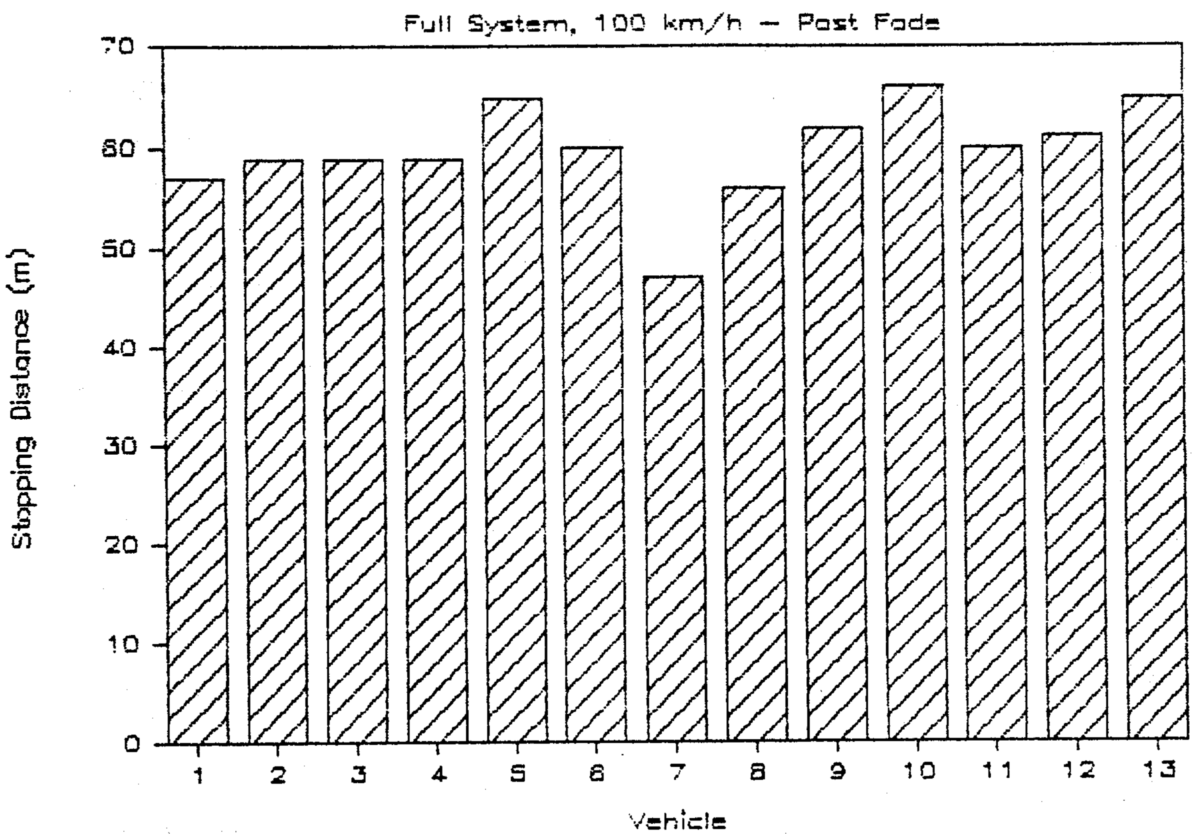


Figure 15



Full System, 100 km/h — Post Fade
Stopping Distance (m)
0
10
20
30
40
50
60
70
1
2
3
4
5
6
7
8
9
10
11
12
13
Vehicle

FIGURE 16

the 13 light trucks to the 19 passenger cars are shown in Figures 17 - 21 for each of the major test segments. The ends of the bars in these figures indicate the 95 percent confidence limits in vehicle performance and the line inside the bar shows the average for all of the vehicles. The 95 percent confidence limit was used for this comparison to eliminate differences due to sample size.

Figure 17 shows the comparison of the results of the full system tests. This figure shows that the difference in the average performance is less than 3 m (10 ft). The comparison of the calculated deceleration for the 80 percent of V_{max} test is shown in Figure 18. The average performance of the two sets of vehicles are within 0.4 m/s^2 (1.3 ft/s^2). The comparison of the failed system tests are shown in Figure 19. The circuit failure results are for both circuits taken together. Comparing the two sets of vehicles, the light trucks stopped an average of 12 m (39 ft) shorter in the laden failed system test, 4 m (13 ft) longer in the inoperative power tests and 2 m (7 ft) longer in the unladen failed system tests.The light trucks had some vehicles with sigfnificantly longer stopping distances on the circuit failure tests resulting in wider confidence limits. This may be due to the fact that more of the light trucks had front/rear plumbing splits than did the cars. Comparisons of the fade and recovery performance are shown in Figure 20 for the stopping distances and Figure 21 for the ratios of the hot performance to the best cold stop and the recovery performance to the best cold stop. The averages on these tests show the light trucks averaged 4 m (13 ft) shorter on the hot stop and 1 m (3 ft) longer on the recovery stop making the average ratios the same for the hot stop and 6 percent smaller on the light trucks for the recovery stop. The confidence limits for these tests are larger for the cars than the light trucks.

4.0 CENTER OF GRAVITY HEIGHT MEASUREMENT

This section of the report describes the method of measuring the center of gravity heights and moments of inertia of the vehicles.

FMVSS 135 Notice 4 Tests
Light Truck and Passenger Car Comparison
Full System Tests

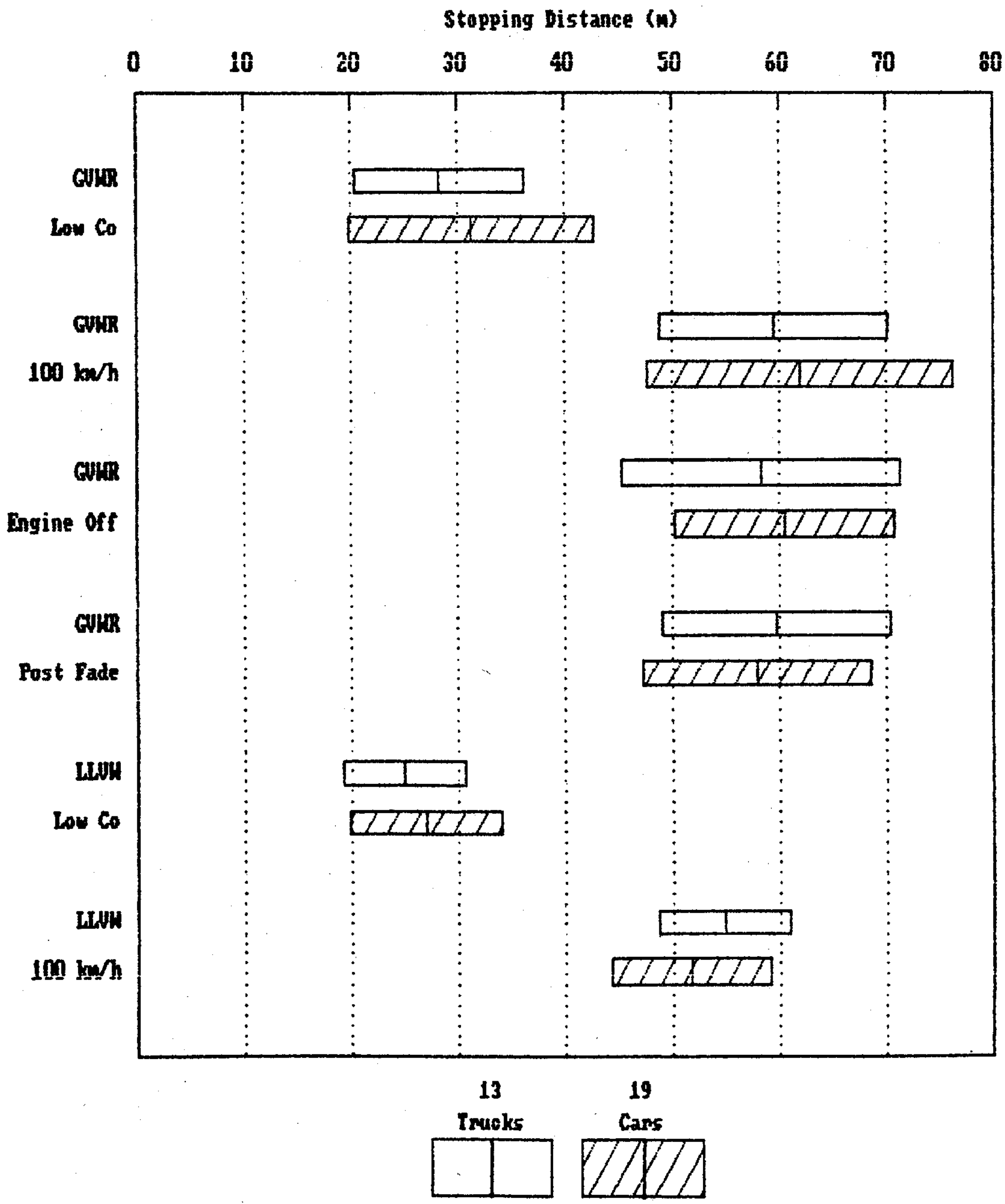


Figure 17

FMVSS 135 Notice 4 Tests
Light Truck and Passenger Car Comparison
Full Service Braking - 80 % Vmax Tests

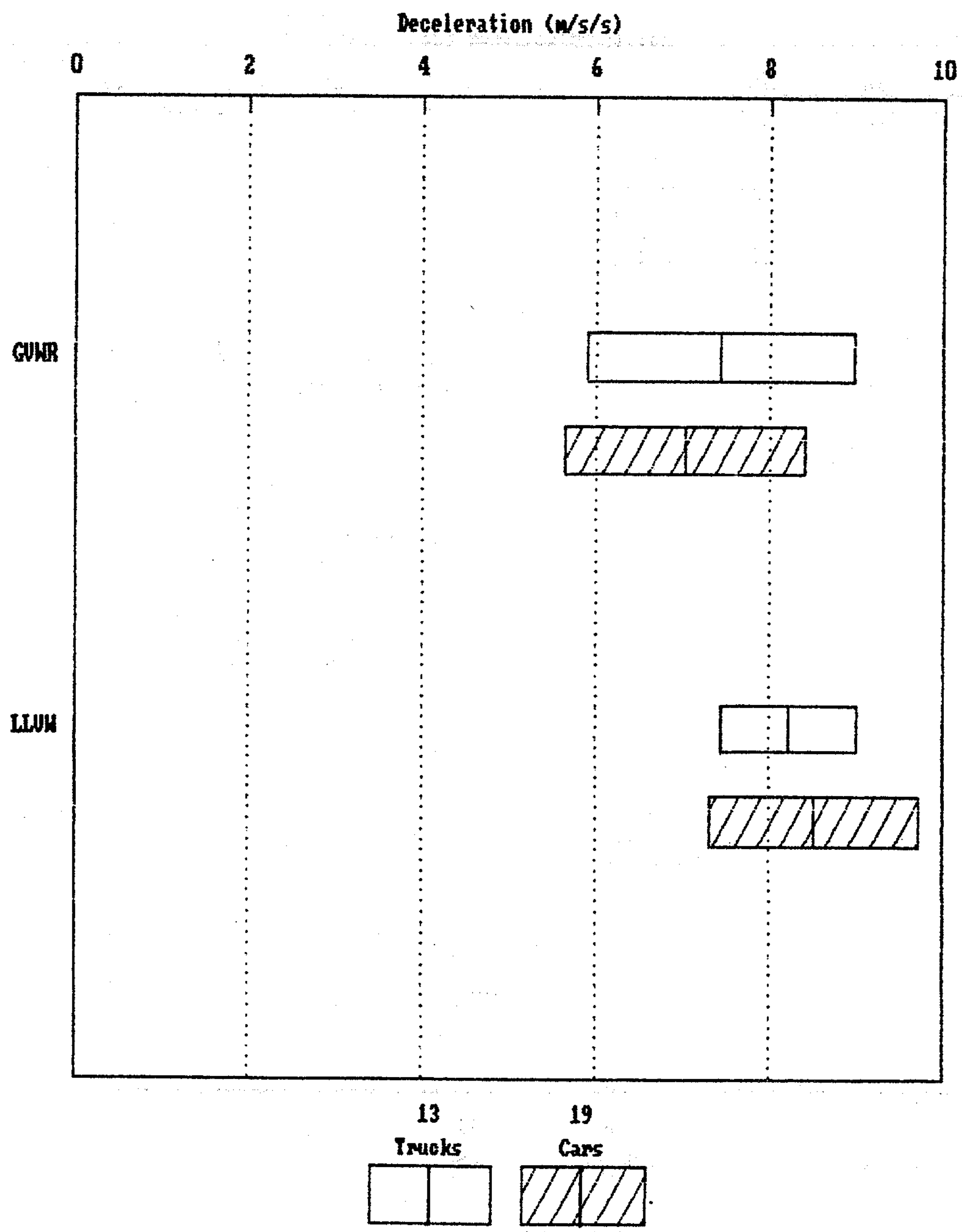


Figure 18

FMVSS 135 Notice 4 Tests
Light Truck and Passenger Car Comparison
Failed System Tests

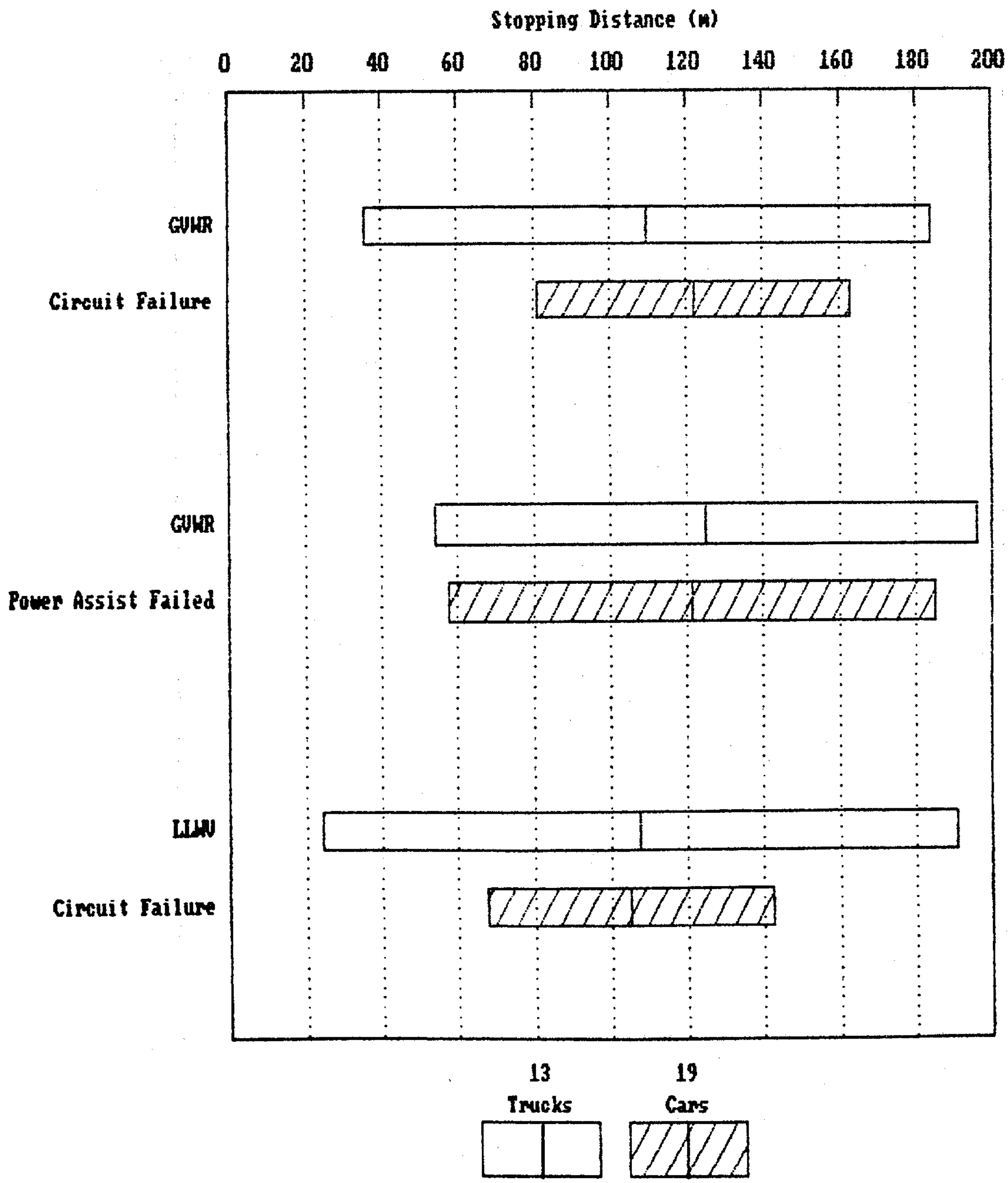


Figure 19

FMVSS 135 Notice 4 Tests
Light Truck and Passenger Car Comparison
Fade and Recovery Performance Stopping Distance

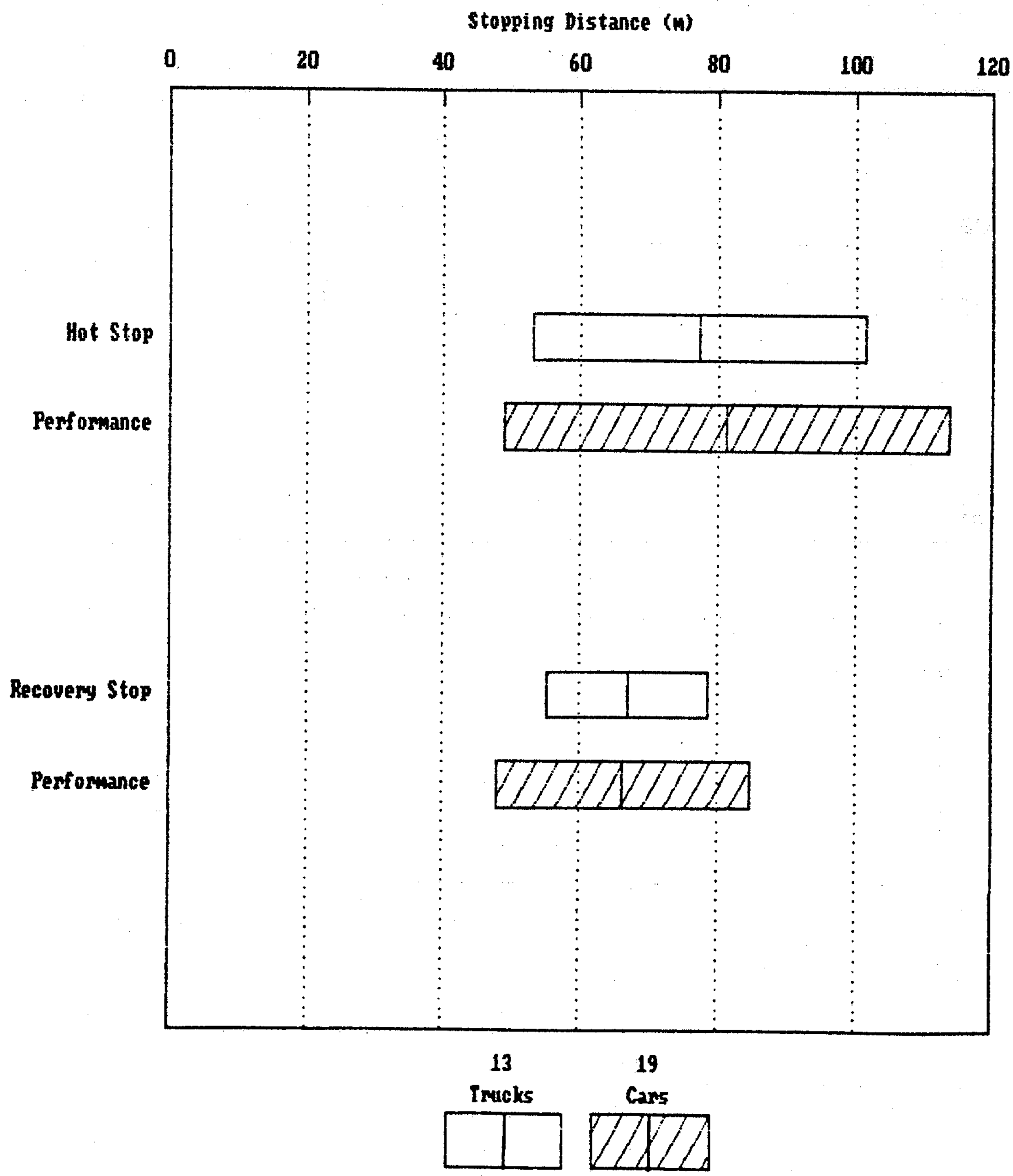


Figure 20

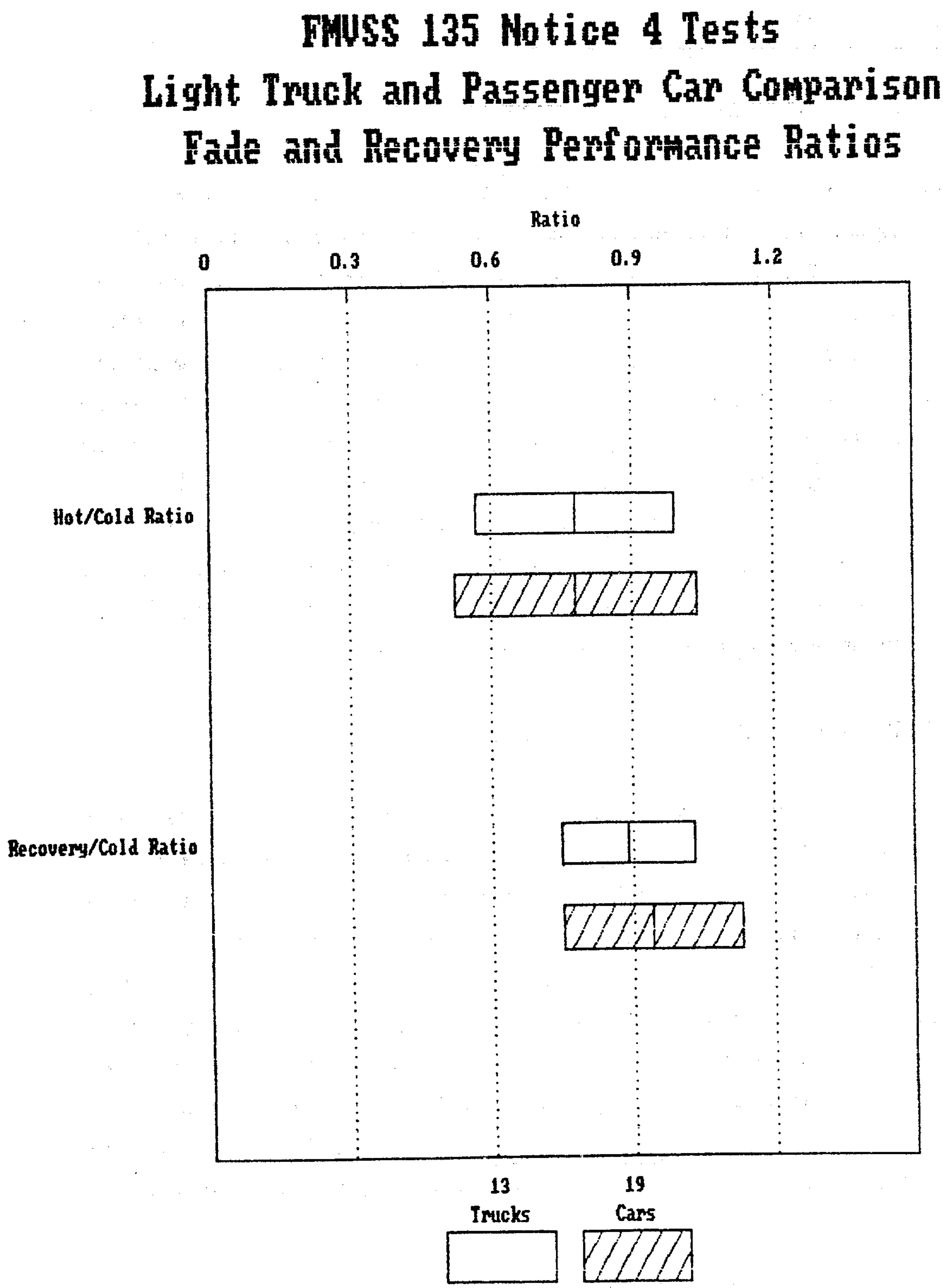

FMVSS 135 Notice 4 Tests
Light Truck and Passenger Car Comparison
Fade and Recovery Performance Ratios
Ratio
0
0.3
0.6
0.9
1.2
Hot/Cold Ratio
Recovery/Cold Ratio
13
Trucks
19
Cars

Figure 21

Additional tests were run on the Chevrolet S-10 and the Ford Ranger to evaluate the effect of load height on stopping distance. The results of these tests will be discussed in this section.

4.1 Test Procedure - Center of Gravity Heights

The center of gravity heights were measured using the device shown in Figure 22. This device and its use is described in detail in Reference 7. The vehicle is driven onto ramps so that the center of gravity is centered over the pivot point of the platform. The platform is raised and known torques are applied to the platform pivot. By measuring the angular displacement of the device for each torque input, the center of gravity can be determined. By allowing the device to swing freely and measuring the period of oscillation, the pitch moment of inertia can be determined. The vehicle can be repositioned so that the roll moment of inertia can be determined in the same way. Springs are attached to a free turning table on the device to allow the measurement of the yaw moment of inertia.

4.2 Test Results - Center of Gravity Heights

The center of gravity heights were measured in three load configurations; curb weight configuration, lightly loaded test configuration and the fully loaded test configuration. The center of gravity heights for each of these load conditions are shown in Table 5. For the Ford E-250 and the Chevrolet C-1500, the center of gravity heights could not be measured in the fully loaded configuration due to constraints on the test device. These values were estimated based on the unladen CG height, the load, and the change in the height of the vehicle above the ground with the change in load. The center of gravity height of the E-250 van in the curb weight condition was not measured.

To investigate the effect of load height on stopping distance, a load rack was built to be used on the Chevrolet S-10. With this load rack, shown in Figure 23, the load could be moved to various heights.

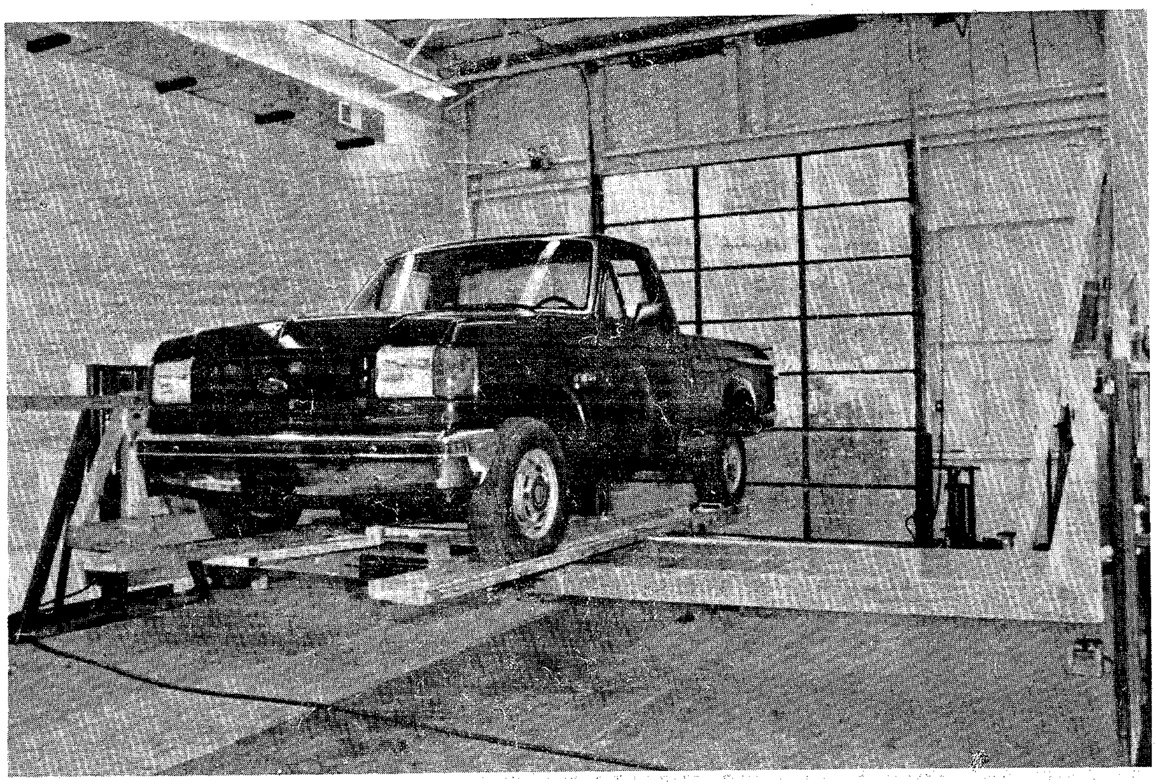


FIGURE 22 -- Vehicle on IPMD

TABLE 5 -- Center of Gravity Heights

Vehicle	Curb (mm)	Unladen (mm)	Laden (mm)
Dodge Caravan	683	692	667
Toyota Van	684	685	712
Chevrolet Astro	749	749	805
Ford E-250	NA	771	734*
Nissan Truck	608	606	635
Chevrolet S-10	618	639	697
Ford Ranger	619	658	659
Ford F-150	704	706	734
Chevrolet C-1500	734	763	745*
Ford F-150 4X4	706	737	794
Dodge Dakota	600	617	625
Toyota 4-Runner	737	766	805
Jeep Cherokee	693	710	700

*CG height estimated

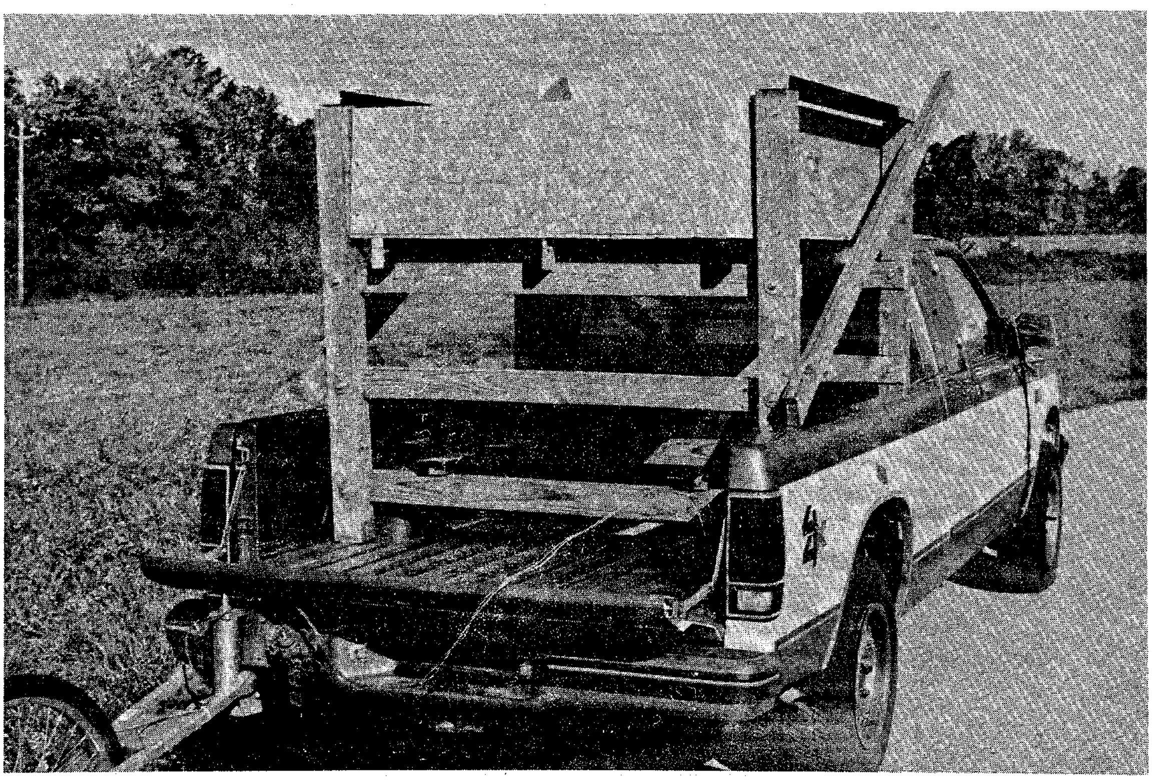
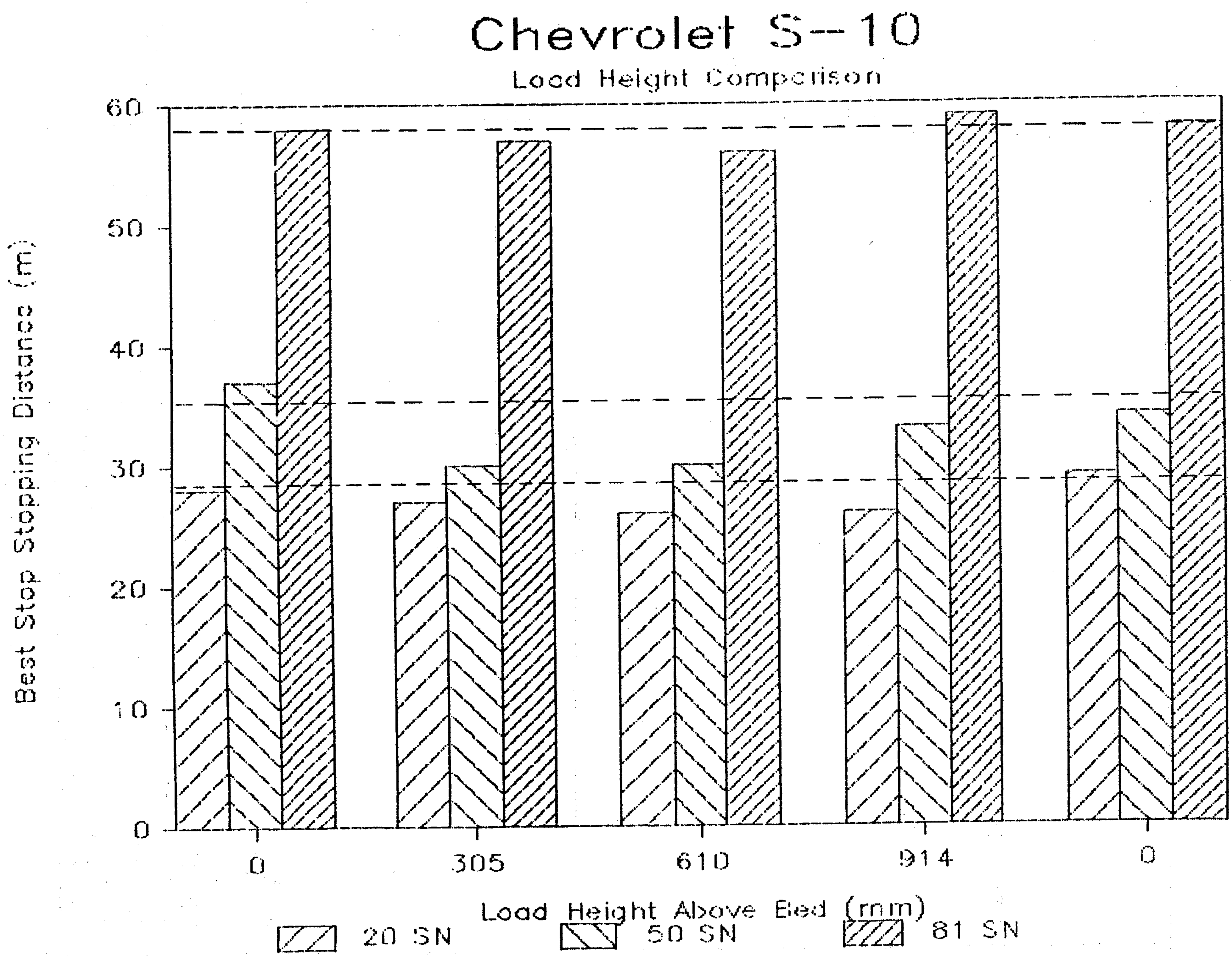


FIGURE 23 -- Chevrolet S-10 With Load Rack

The load heights used included having the load in the bed, at 305 mm (12 in) above the bed, 610 mm (24 in) above the bed and 914 mm (36 in) above the bed. These load configurations resulted in center of gravity heights of 697 mm, 760 mm, 823 mm and 886 mm respectively. At each load height, six best effort stops were made on each of three surfaces and an RTP test was run. The stops were made on a 20 SN surface from 50 km/h, a 50 SN surface from 65 km/h and a 80 SN surface from 100 km/h. At the conclusion of these tests, the stops with the load in the bed were repeated to determine if any conditioning of the brake system had occured which would confuse the test results. Figure 24 shows the stopping distance results for each of the configurations. The dashed lines on the figure represent the average stopping distance for the two tests with the load in the bed. The tests on the 20 SN and 81 SN surfaces show essentially no change in stopping distance for the two sets of tests with the load in the bed while the 50 SN surface results show a slight change. The stops on the 20 SN surface show a slight improvement in stopping distance for the higher load heights, however, these differences are small. On the other surfaces, the results do not show any significant trend with the differences being within normal data scatter. The results for the RTP tests at the various load heights are shown in Appendix E. While the braking forces did not change significantly between the configurations, the braking efficiency changed due to the change in CG height. Figure 25 shows a composite of the braking efficiencies for the four load heights. As can be seen in the figure, the braking efficiency improved slightly for the higher load heights, however, the change is small which agrees with the results of the stopping distance tests.

The same load rack was used in the Ford Ranger and six best effort stops were made on the same three surfaces with the load in the bed and elevated 914 mm. The center of gravity heights for the two load configurations were 659 mm (25.9 in) and 830 mm (32.7 in). Figure 26 shows the results of these stopping distance tests. The differences in the distances for the two load heights are relatively small. The 81 SN surface results are the same while on the 20 SN surface the elevated load gave slightly shorter stops and on the 50 SN



Chevrolet S-10
Load Height Comparison
Best Stop Stopping Distance (m)
0
10
20
30
40
50
60
0
305
610
914
0
Load Height Above Bed (mm)
20 SN
50 SN
81 SN

FIGURE 24

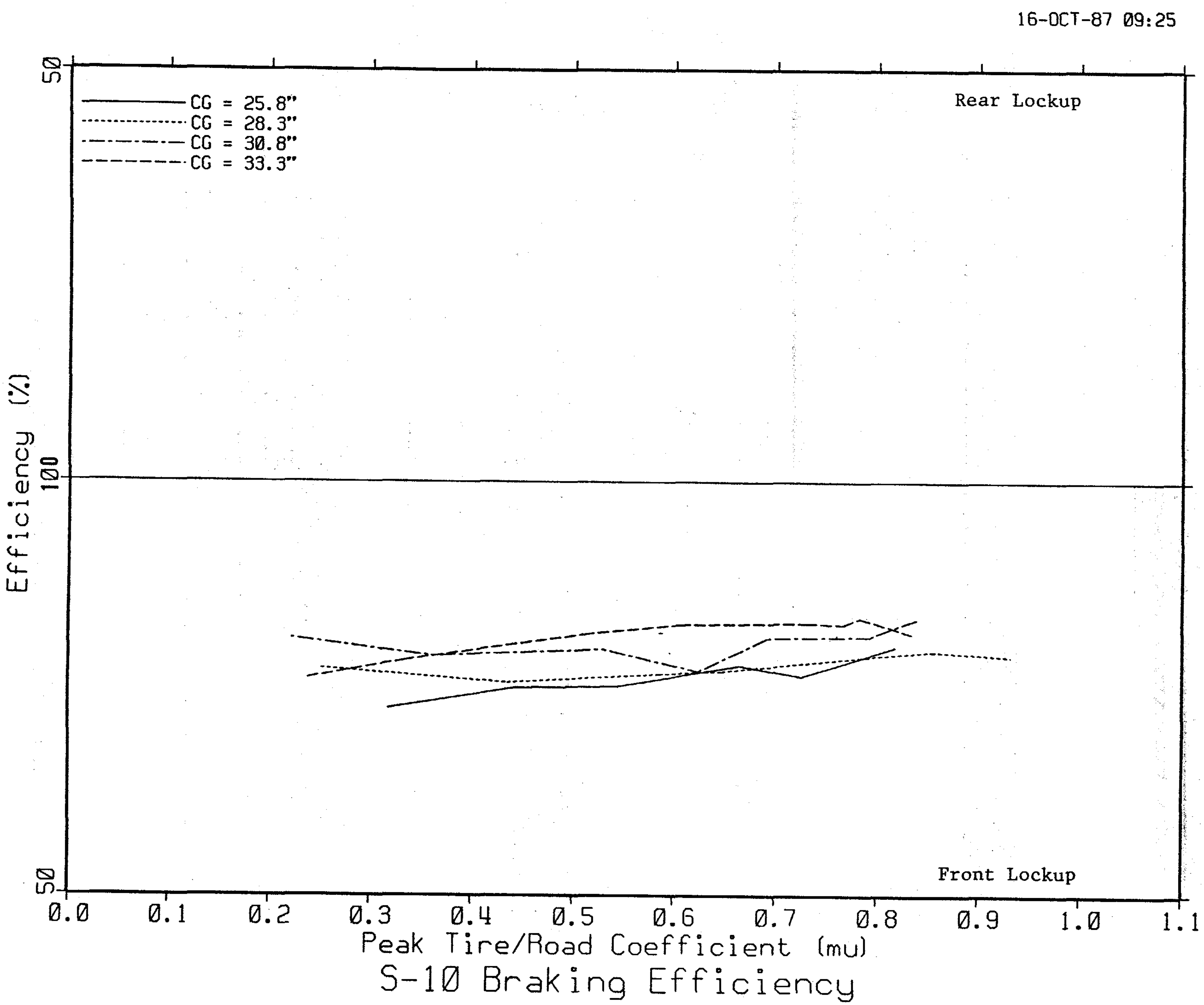

16-OCT-87 09:25
CG = 25.8"
CG = 28.3"
CG = 30.8"
CG = 33.3"
Rear Lockup
Front Lockup
Efficiency (%)
50
100
50
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
Peak Tire/Road Coefficient (mu)
S-10 Braking Efficiency

FIGURE 25

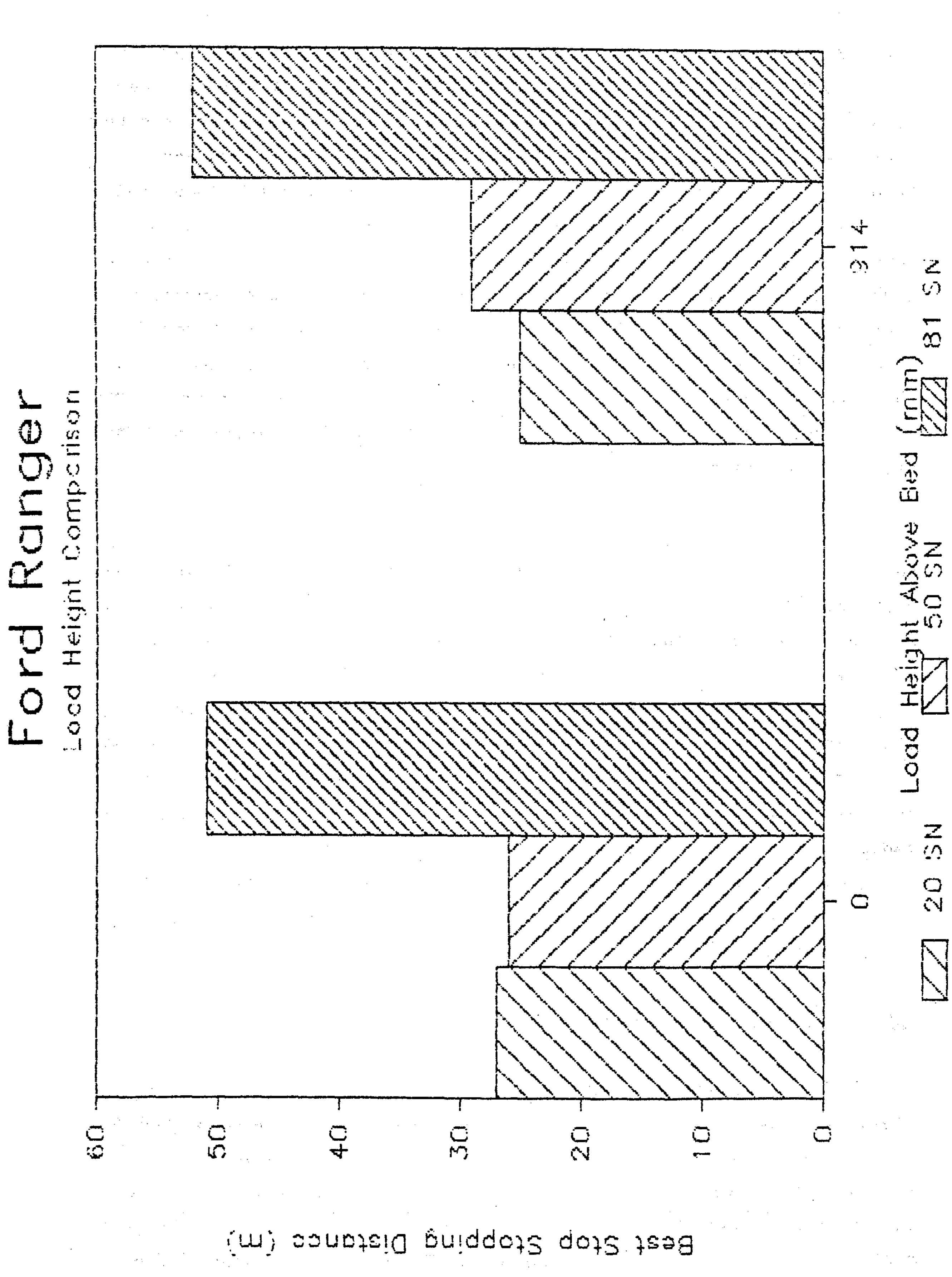

Ford Ranger
Load Height Comparison
Best Stop Stopping Distance (m)
0
10
20
30
40
50
60
0
314
Load Height Above Bed (mm)
20 SN
50 SN
81 SN

FIGURE 26

surface the stops were slightly longer with the elevated load. An axle lock sequence was run on the 20 and 50 SN surfaces with both loads. On the 20 SN surface, the front axle locked first in both configurations. With the load in the bed on the 50 SN surface, the front axle locked first but showed nearly ideal balance (the front axle locked first on two stops and the rear axle locked first on the other stop). With the load elevated on this surface, the rear axle locked first. RTP tests were run in both of the load configurations, however, some conditioning of the brakes occured during the time between the two tests which changed the performance of the brakes. The two RTP tests (results included in Appendix E) showed significant differences in the braking forces which made the results of these tests inconclusive.

The results of the tests with elevated loads indicate that the height of the load did not have a significant affect the stopping distance performance. For these two vehicles, the load height was changed an extreme amount (914 mm) which changed the vehicle center of gravity height 189 mm (7.4 in) on the S-10 and 171 mm (6.7 in) on the Ranger. Even with this change in load and CG height, the stopping distance performance change was small. The lockup sequence results changed on the Ranger with the change in load height, but only on a surface where the brake balance was near ideal. The results on this vehicle were also effected by a change in the brake system balance due to conditioning. Further investigation is needed to better quantify the importance of load height on tests such as a lockup sequence for vehicles with near ideal brake balance.

5.0 BRAKE BALANCE MEASUREMENTS

This section of the report describes the methods used to determine the vehicle braking balance and shows the results of these tests. At the time this program was started, the RTP was not in operation, so it was decided that the brake balance would be established by rebuilding the brake system, burnishing the brakes according to the FMVSS 135 Notice 4 procedure, and running a test to measure the brake balance rather than conditioning the brakes during the FMVSS 135 Notice 4 tests. Since an RTP test does little conditioning of the brakes, the brake balance of some of the vehicles was measured on the RTP during the axle sequence tests described above in addition to the tests discussed here. A comparison of the brake balance of the light trucks will be made to the brake balance of the 19 passenger car sample.

5.1 Test Procedure - Brake Balance Tests

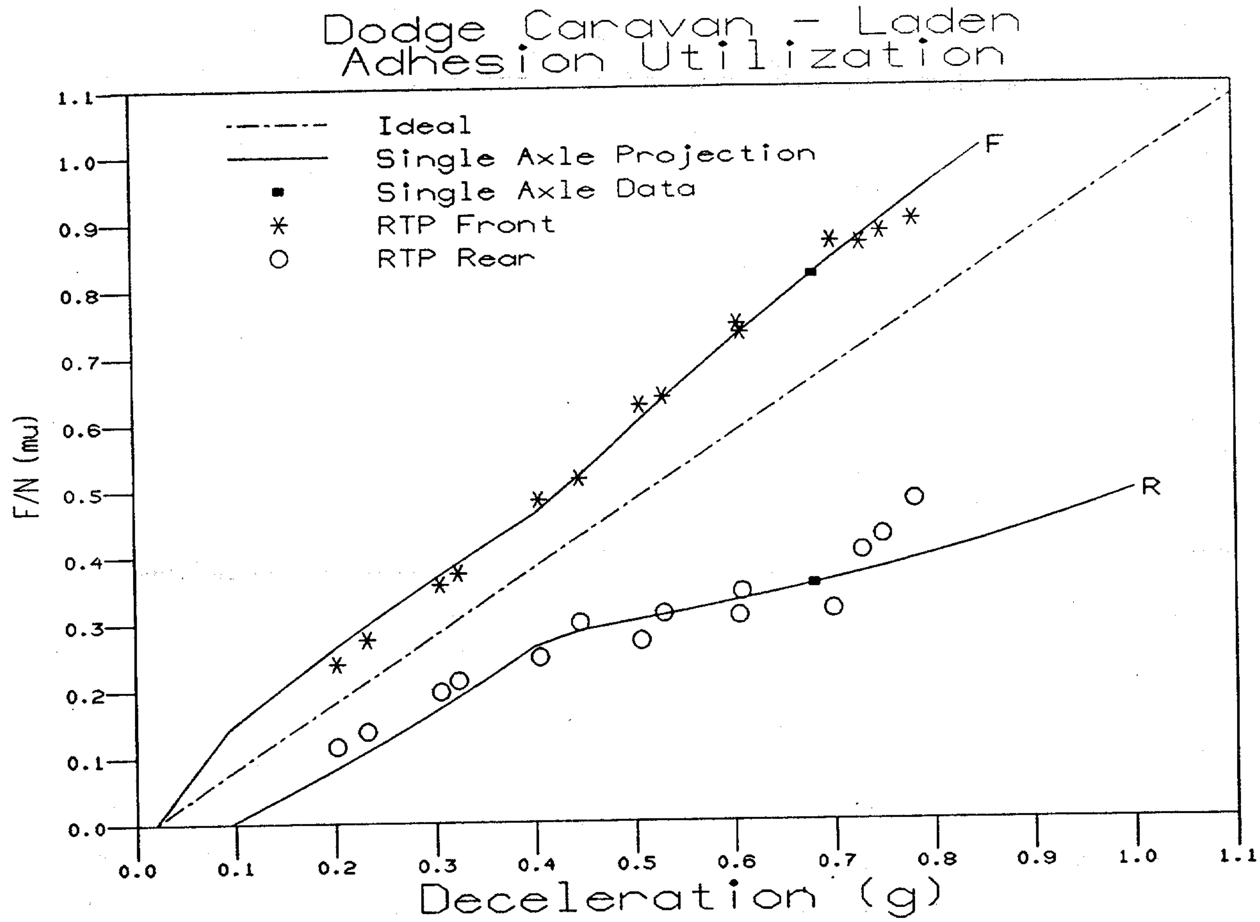
The brake balance for ten of the vehicles was measured in two ways. For all 13 of the vehicles, new brakes were installed and burnished per FMVSS 135 Notice 4 and the brake balance was measured using a method similar to that described in Reference 8 hereafter referred to as the single axle procedure. This method consists of making snubs with only the front axle brakes operational and then only the rear axle brakes operational. By measuring the time between two speeds, the deceleration and, therefore, the braking force can be calculated. The brake line pressure was measured during these snubs. The braking force as a function of brake pressure is then determined by the straight line defined by the measured braking force and brake pressure and the brake pushout pressure at zero braking force. The proportioning valve characteristics were also determined so for any front brake pressure, the front axle braking force, rear brake pressure and rear axle braking force could be calculated. Given this information and vehicle static weights, wheelbase and center of gravity height, the deceleration and adhesion utilization could be calculated. For vehicles with fixed proportioning valves, the proportioning valve characteristics were determined by making static brake applications to various levels while recording the front and rear brake line pressures. To determine the proportioning valve characteristics for vehicles with variable proportioning valves, snubs were made, in addition to the static brake applications, at various deceleration levels in both the laden and unladen conditions. Variable proportioning valves use a set front to rear pressure ratio and vary the break point depending on load or deceleration. From the static test, the slope of the curve beyond the break point was determined. From the dynamic tests, the relationship between the break point and rear axle load or deceleration was determined. In this fashion, the adhesion utilization characteristics were determined.

The second method used to determine the front to rear brake balance was with the RTP. The RTP was used for 10 of the 13 vehicles. For 8 of the vehicles, an RTP test was run in both load conditions both before and after the single axle distribution test and the remainder of the vehicles were run in only some of the conditions. Some of the scatter in the RTP data for those vehicles where the RTP was run both before and after the single axle test is due to conditioning changes of the brakes during the single axle test. The results from both methods will be shown below where available.

All of the plots shown in this section of the report show performance with the vehicle in gear. For the vehicles with standard transmissions, the gear used for the test was the appropriate gear for normal driving at the test speed.

5.2 Test Results - Brake Balance Tests

The adhesion utilization and braking efficiency plots for the laden Dodge Caravan are shown in Figure 27 and in Figure 28 for the unladen configuration. The adhesion utilization curve is interpreted by finding the peak tire/road coefficient of friction (mu) of interest along the verticle axis. The first line crossed when following horizontally across from this point (the line for the front axle in this case) is the axle which will lock first on the given surface. The smooth lines on these plots indicate the projection from the single axle test with the solid square indicating the point where the data was actually taken. The symbols on the plots show the results from the RTP tests. The braking efficiency plots also show which axle locks first by showing the line either above (rear biased) or below (front biased) the 100 percent efficiency line. The braking efficiency is read from this plot by finding the point on the curve


Dodge Caravan - Laden
Adhesion Utilization
Ideal
Single Axle Projection
Single Axle Data
RTP Front
RTP Rear
F
R
F/N (mu)
Deceleration (g)

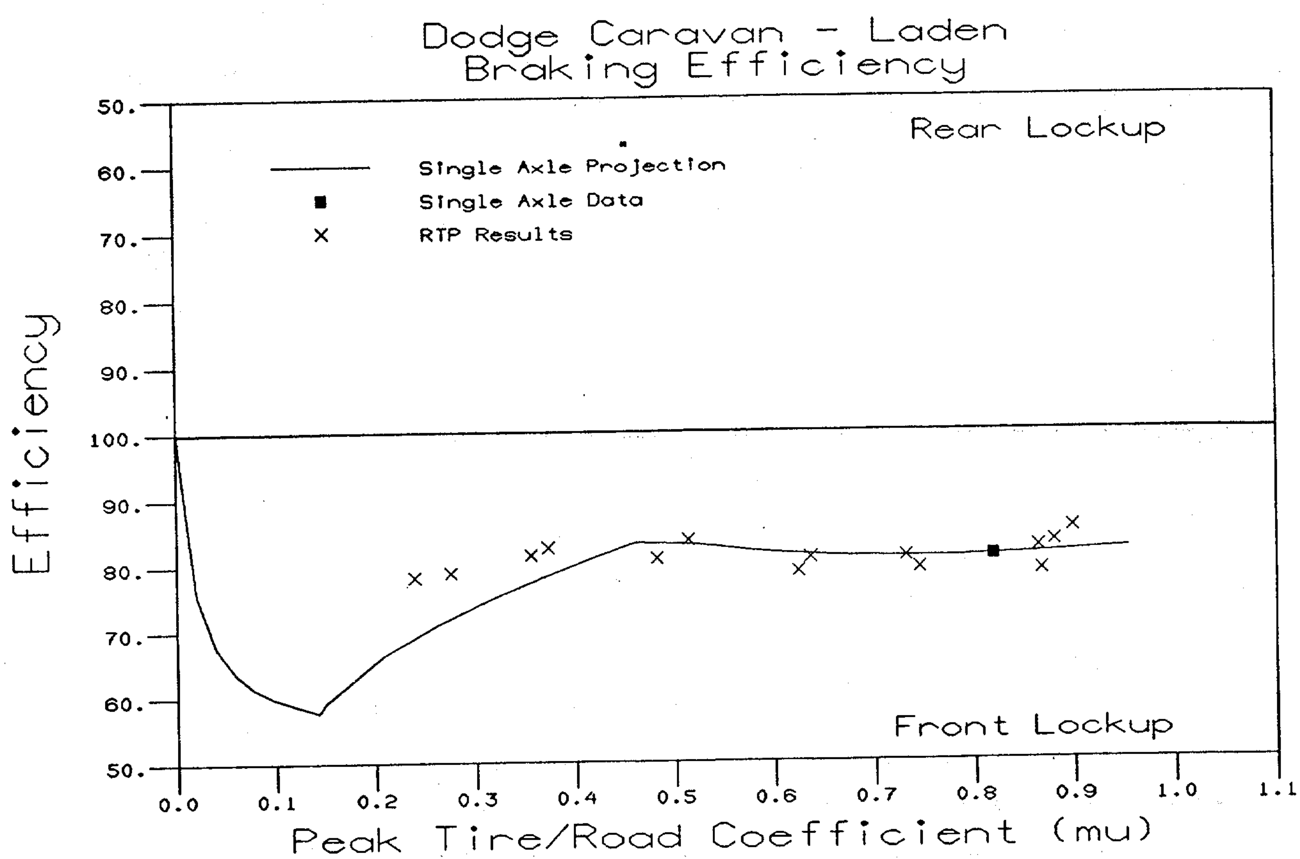
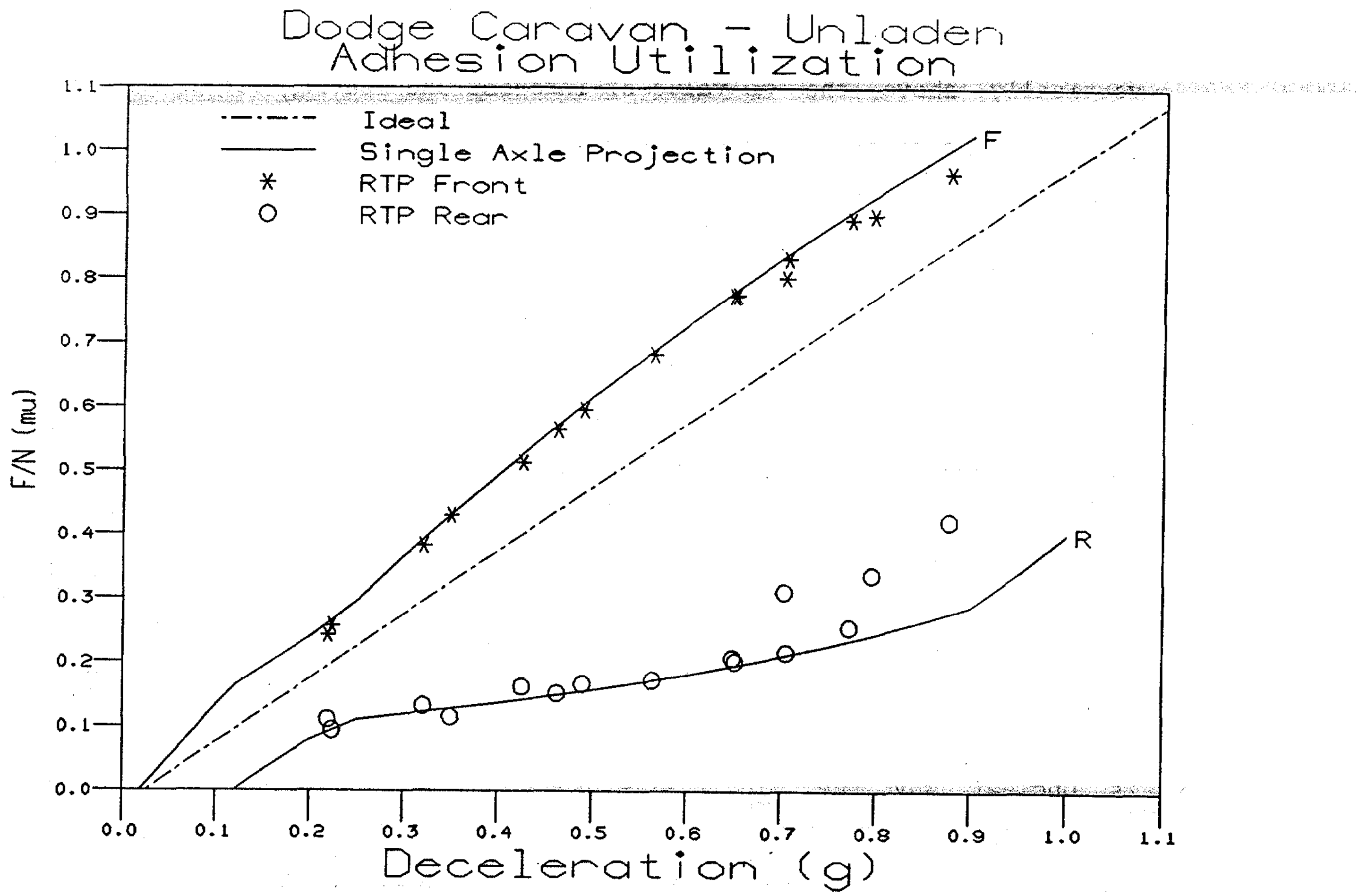

Dodge Caravan - Laden
Braking Efficiency
Rear Lockup
Single Axle Projection
Single Axle Data
RTP Results
Front Lockup
Efficiency
Peak Tire/Road Coefficient (mu)

FIGURE 27


Dodge Caravan - Unladen
Adhesion Utilization
Ideal
Single Axle Projection
RTP Front
RTP Rear
F
R
F/N (mu)
Deceleration (g)

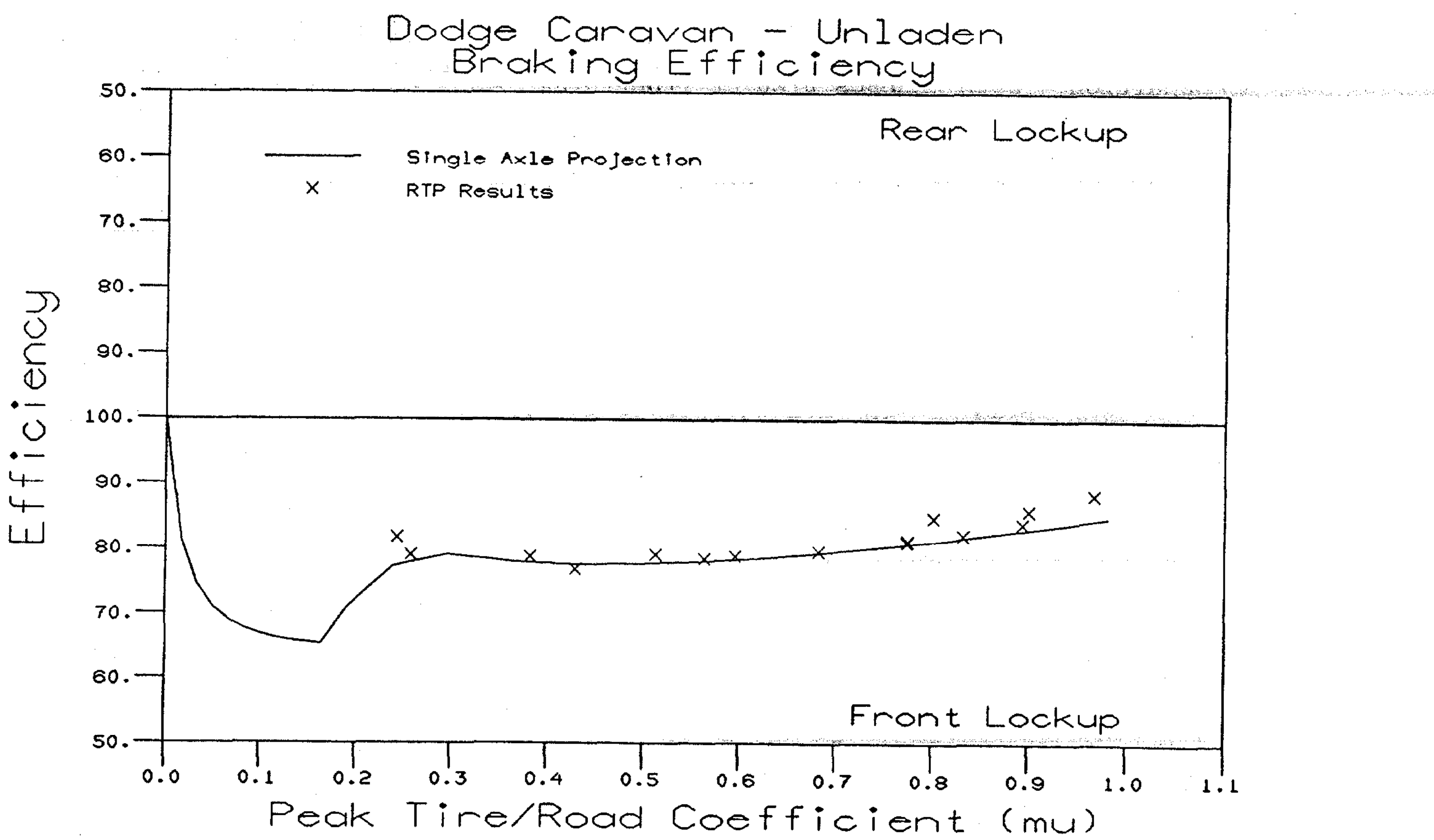

Dodge Caravan - Unladen
Braking Efficiency
Rear Lockup
Single Axle Projection
RTP Results
Front Lockup
Efficiency
Peak Tire/Road Coefficient (mu)

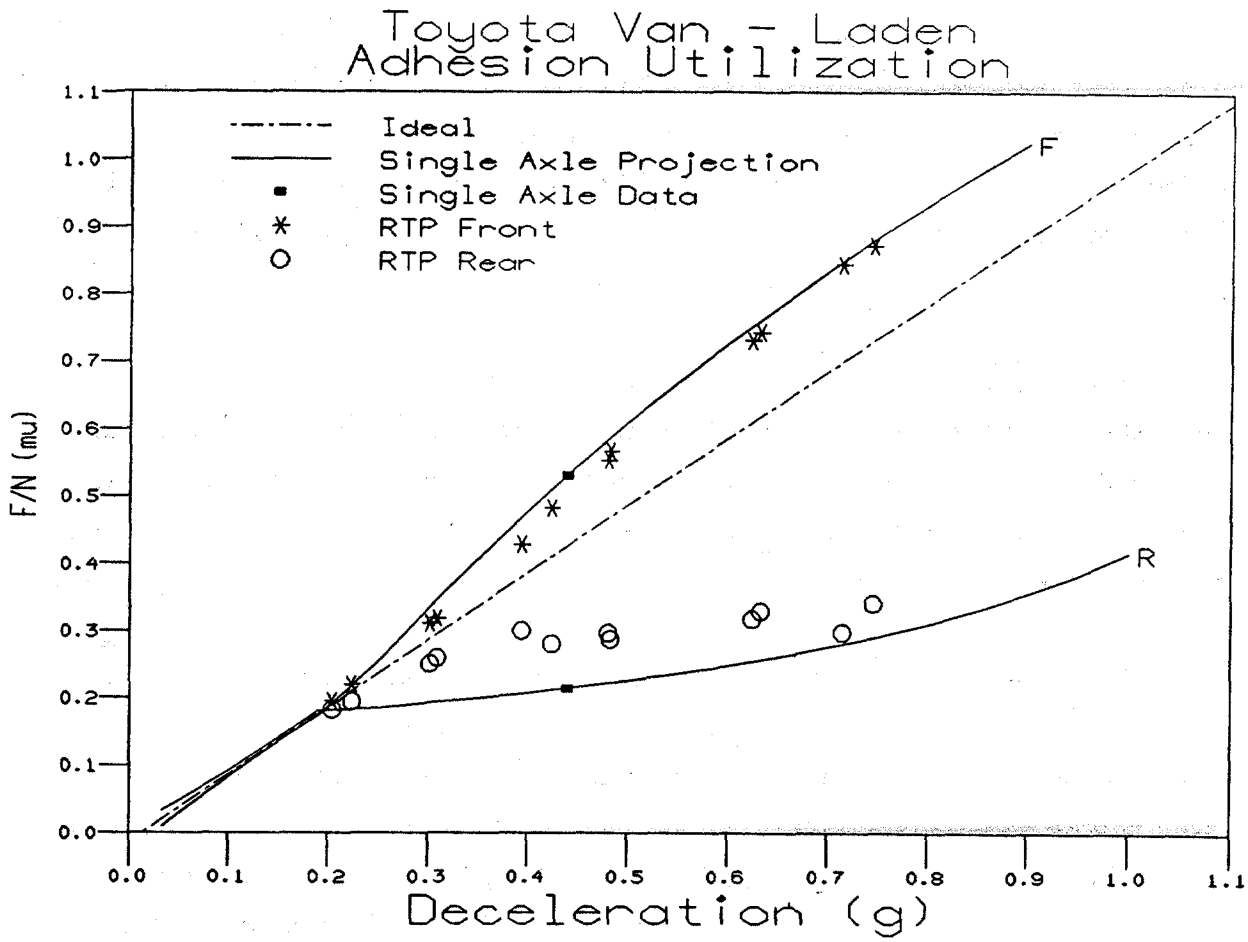
FIGURE 28

vertically above the mu value of interest and reading across to the braking efficiency. For the Dodge Caravan, which was equiped with a height sensing proportioning valve, the plots show that the vehicle is front brake biased in both load conditions and that the single axle projection and the RTP test agree quite well.

The results for the Toyota Van are shown in Figures 29 and 30 for the laden and unladen conditions respectively. This vehicle was equipped with a height sensing proportioning valve. The plot shows that the vehicle is basically front brake biased and that the two test methods agree quite well.

The Chevrolet Astro brake balance plots are shown in Figure 31 for the laden tests and Figure 32 for the unladen tests. The Astro had a conventional brake system with a fixed proportioning valve. It is unclear why the single axle procedure predicted more rear brake bias than did the RTP tests, however, the RTP tests on this vehicle during the axle lock sequence portion of the FMVSS 135 Notice 4 procedure agree quite well with the RTP tests shown here. In the laden condition, both methods predict front brake bias with the single axle projection indicating a higher braking efficiency. In the unladen condition, however, the single axle procedure predicts rear brake lockup above a peak mu of 0.3 while the RTP predicts front bias until a peak mu of around 0.9 to 0.95. Both methods predict a high braking efficiency.

The Ford E-250 van was not tested on the RTP. The results of the single axle test are shown in Figures 33 and 34 for the laden and unladen conditions respectively. This vehicle had a two stage height sensing proportioning valve which set the brake proportioning to one of two levels depending upon the distance between the bed and the rear axle. In the laden configuration, the single axle test predicted front brake bias up to a peak mu of 0.52 with nearly ideal balance for most of the values of mu. In the unladen condition, the vehicle is


Toyota Van - Laden
Adhesion Utilization
Ideal
Single Axle Projection
Single Axle Data
RTP Front
RTP Rear
F
R
F/N (mu)
Deceleration (g)

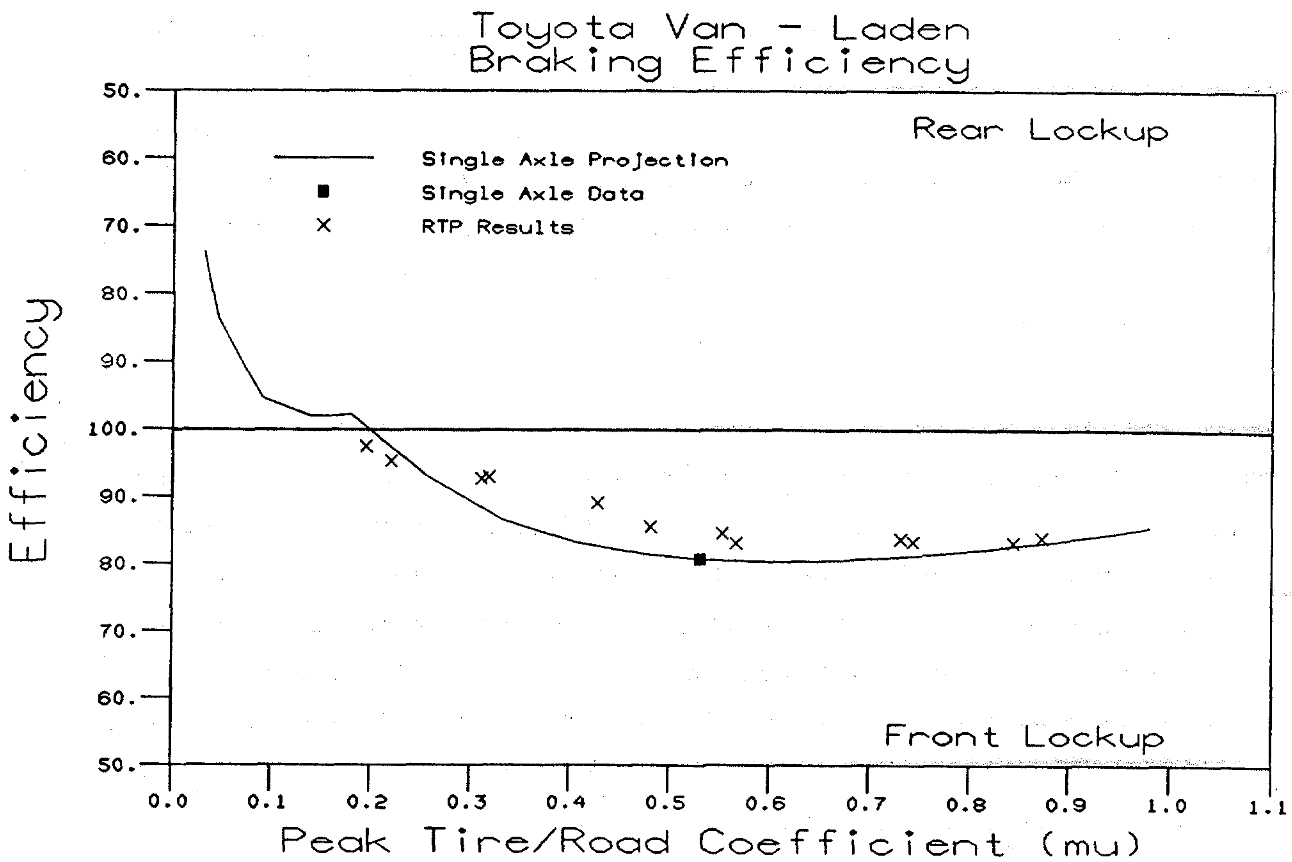

Toyota Van - Laden
Braking Efficiency
Rear Lockup
Single Axle Projection
Single Axle Data
RTP Results
Front Lockup
Efficiency
Peak Tire/Road Coefficient (mu)

FIGURE 29

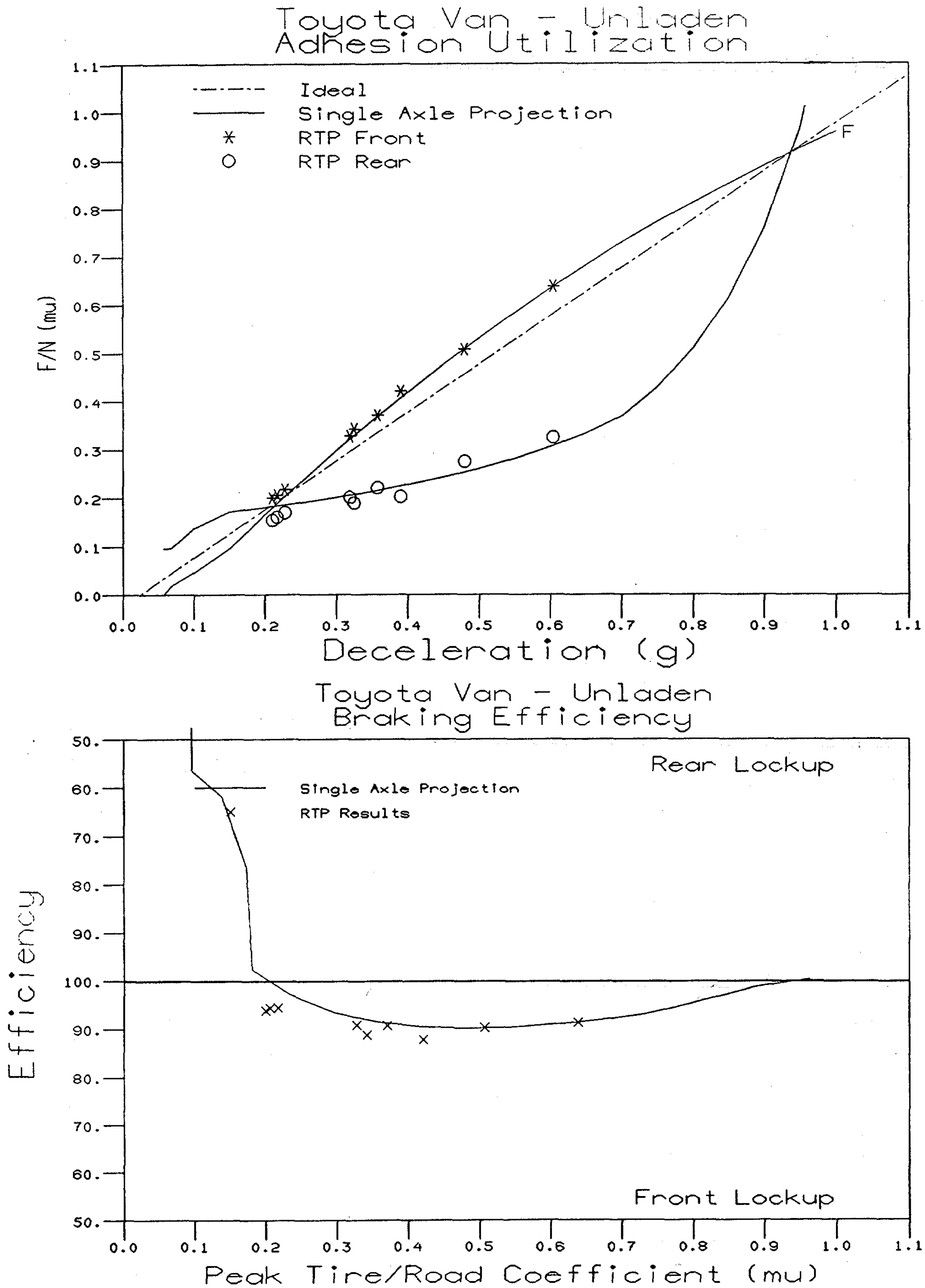

Toyota Van - Unladen
Adhesion Utilization
Ideal
Single Axle Projection
RTP Front
RTP Rear
F
F/N (mu)
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1
Deceleration (g)
Toyota Van - Unladen
Braking Efficiency
Rear Lockup
Single Axle Projection
RTP Results
Front Lockup
Efficiency
50.
60.
70.
80.
90.
100.
90.
80.
70.
60.
50.
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1
Peak Tire/Road Coefficient (mu)

FIGURE 30

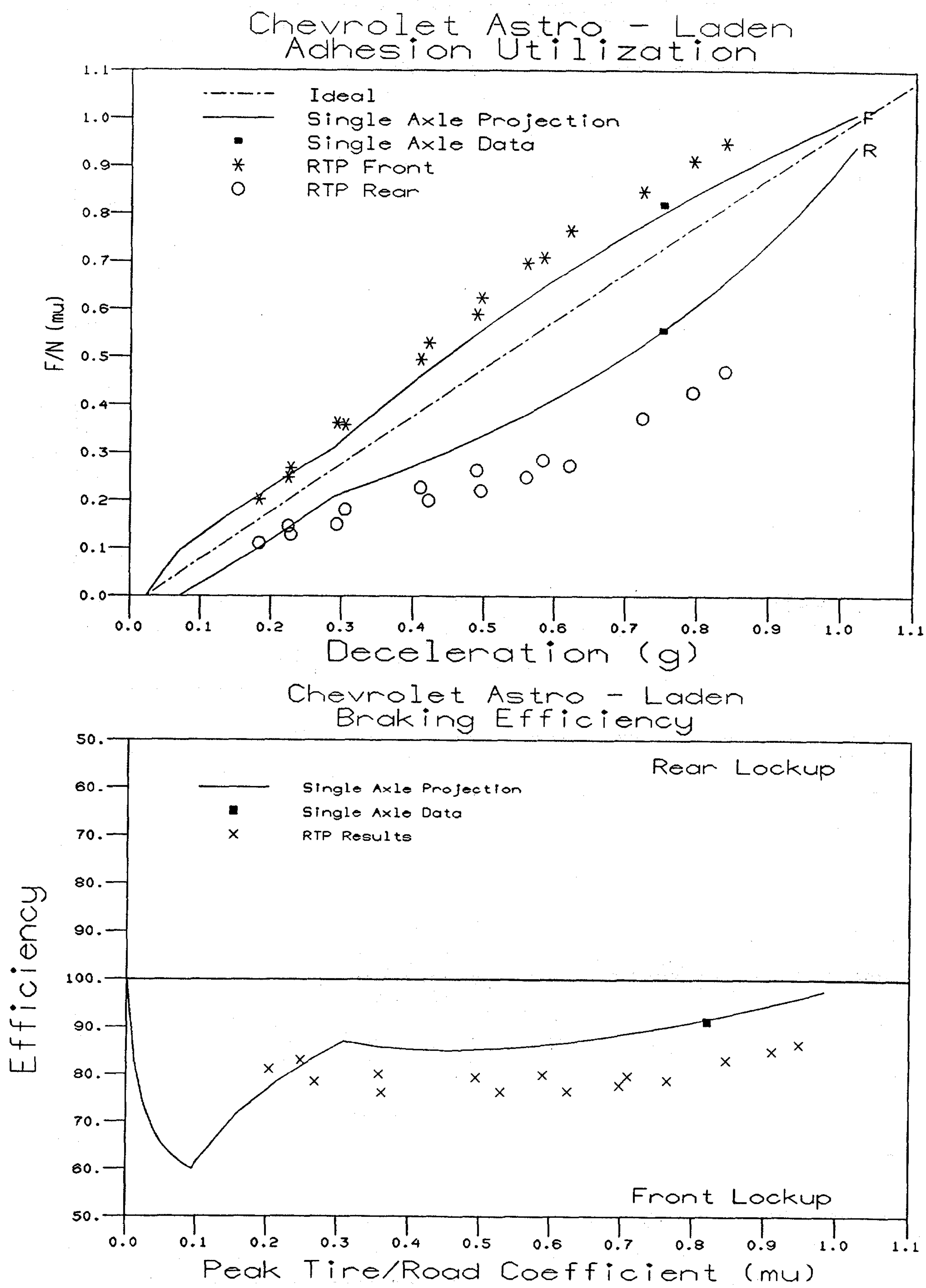
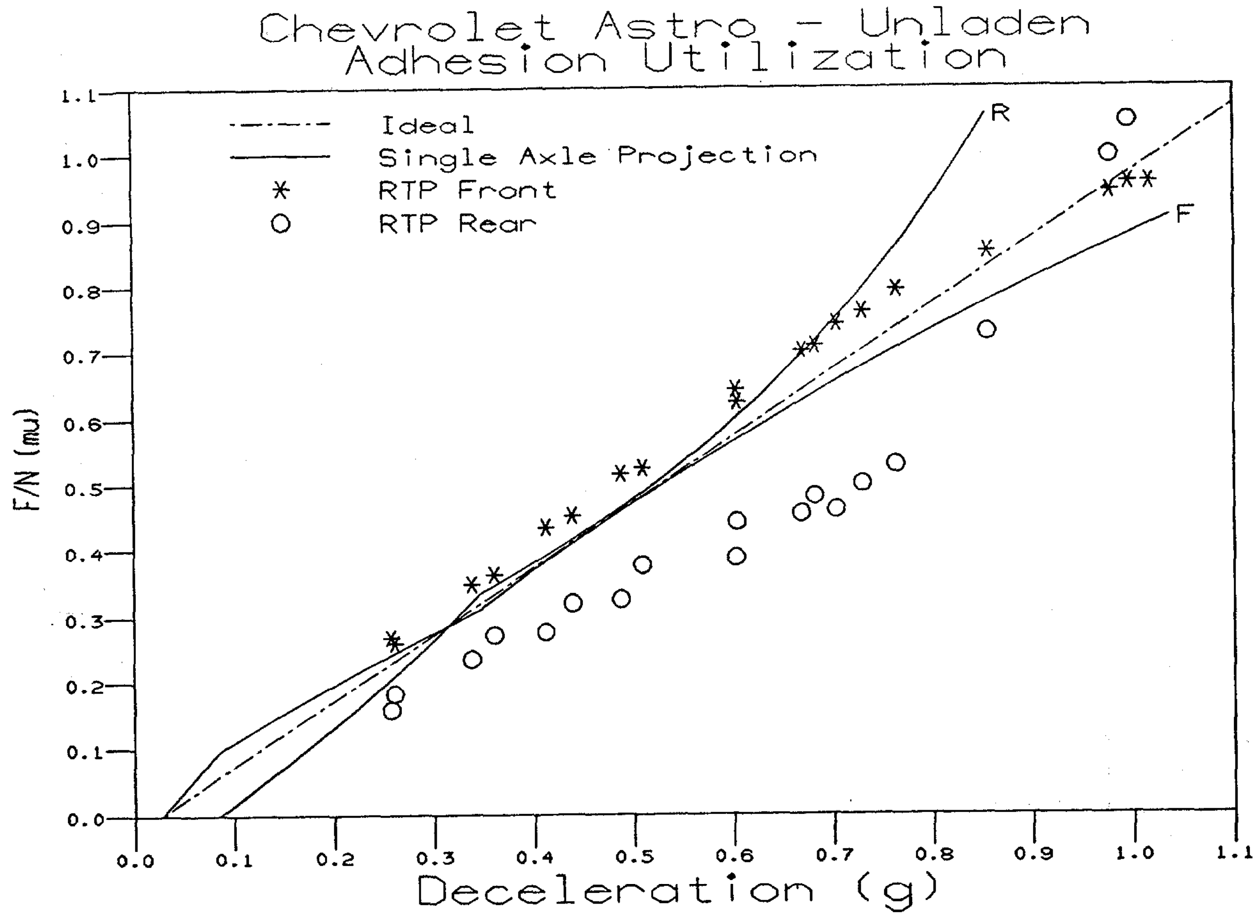

Chevrolet Astro - Laden
Adhesion Utilization
Ideal
Single Axle Projection
Single Axle Data
RTP Front
RTP Rear
F
R
F/N (mu)
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
Deceleration (g)
Chevrolet Astro - Laden
Braking Efficiency
Rear Lockup
Single Axle Projection
Single Axle Data
RTP Results
Front Lockup
Efficiency
50.
60.
70.
80.
90.
100.
90.
80.
70.
60.
50.
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
Peak Tire/Road Coefficient (mu)

FIGURE 31


Chevrolet Astro - Unladen
Adhesion Utilization
Ideal
Single Axle Projection
RTP Front
RTP Rear
R
F
F/N (mu)
Deceleration (g)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1

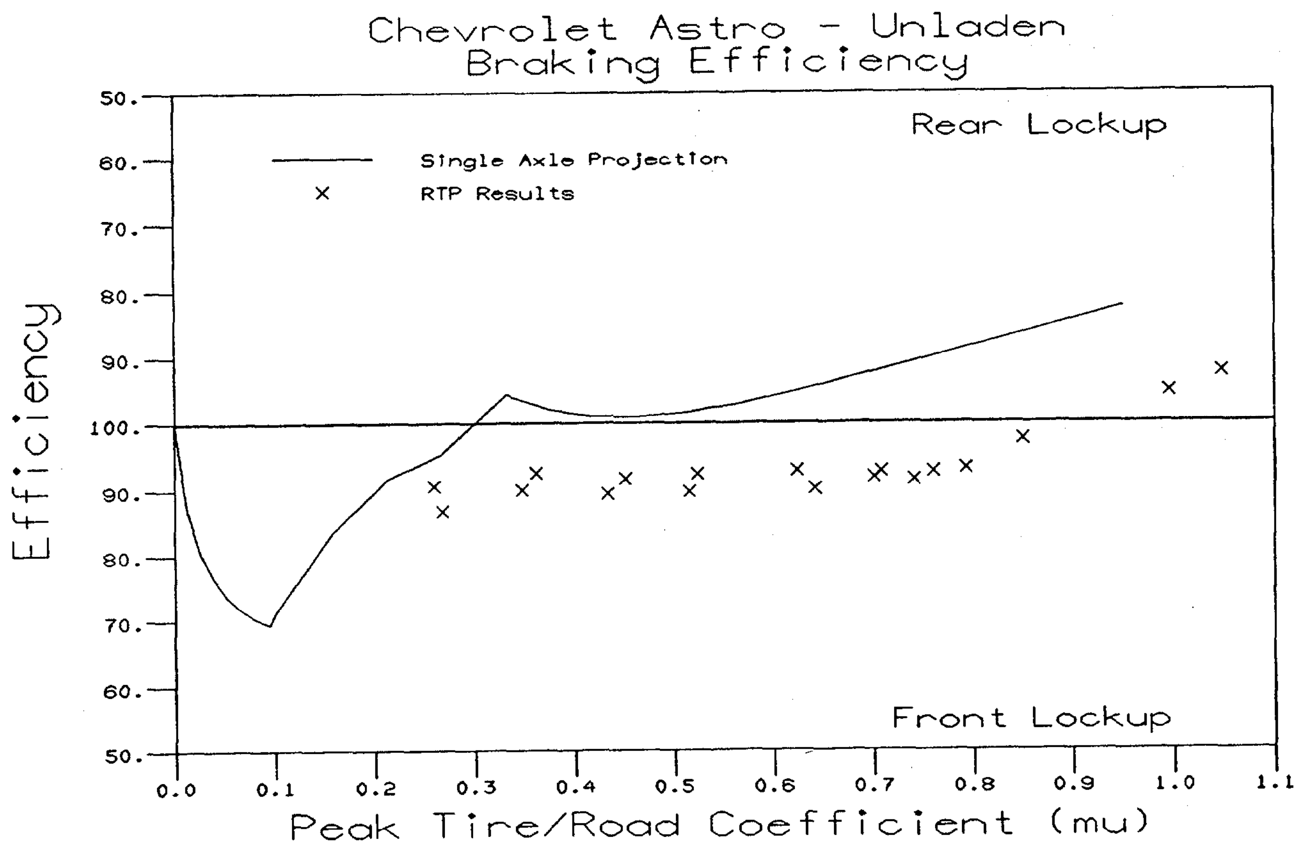

Chevrolet Astro - Unladen
Braking Efficiency
Rear Lockup
Single Axle Projection
RTP Results
Front Lockup
Efficiency
Peak Tire/Road Coefficient (mu)
50.
60.
70.
80.
90.
100.
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1

FIGURE 32

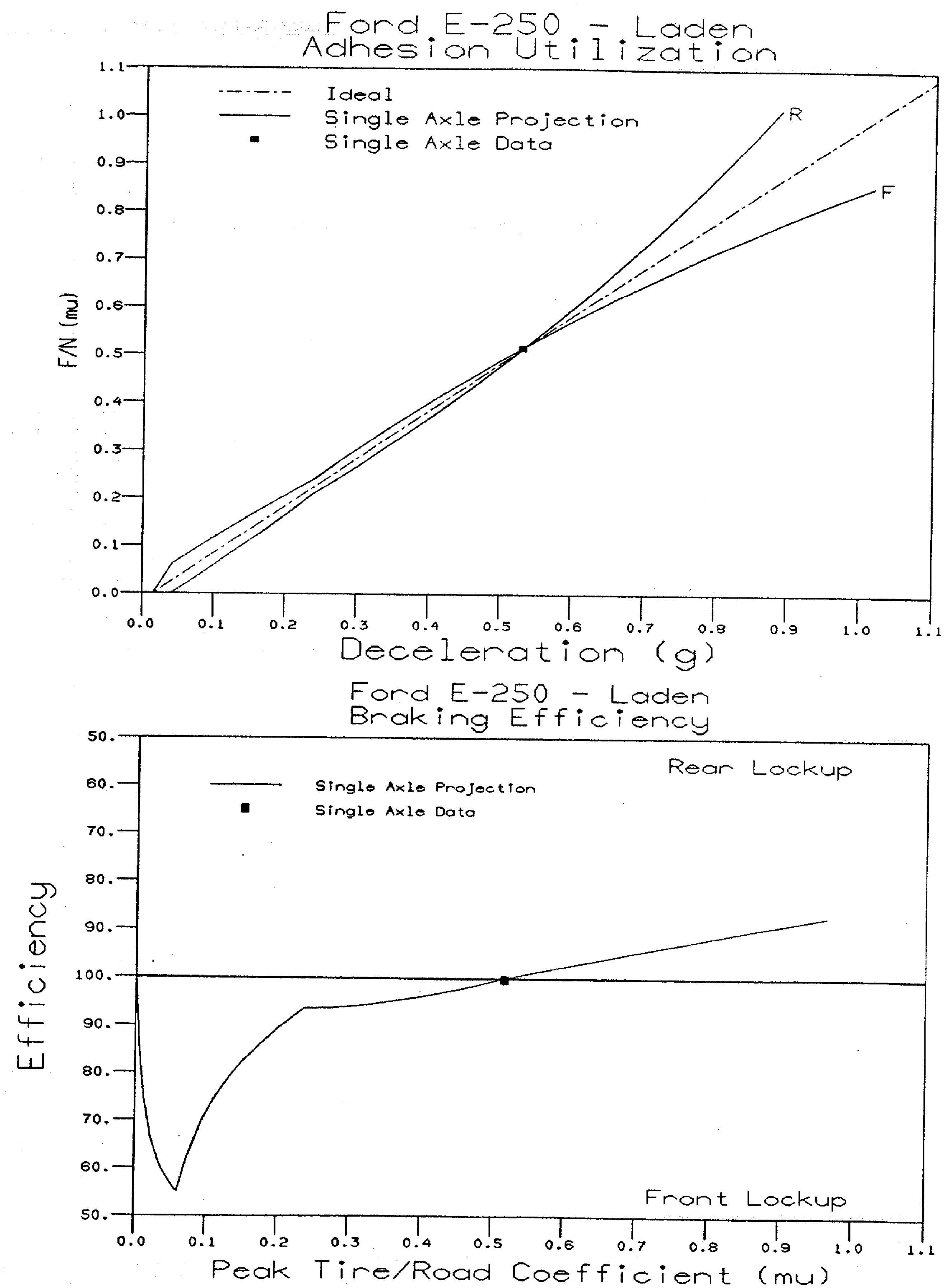
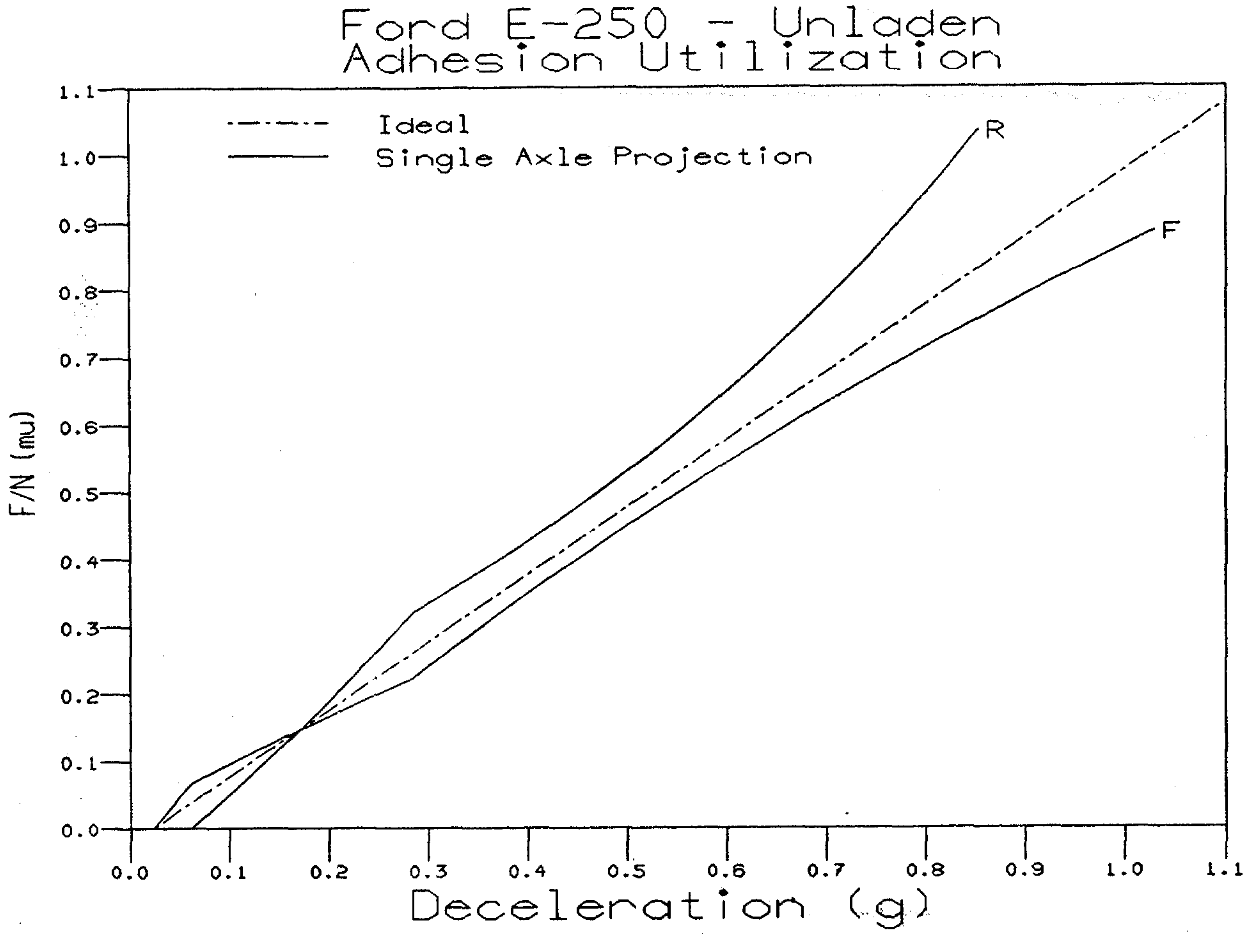

Ford E-250 - Laden
Adhesion Utilization
Ideal
Single Axle Projection
Single Axle Data
R
F
F/N (mu)
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1
Deceleration (g)
Ford E-250 - Laden
Braking Efficiency
Single Axle Projection
Single Axle Data
Rear Lockup
Front Lockup
Efficiency
50.
60.
70.
80.
90.
100.
90.
80.
70.
60.
50.
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1
Peak Tire/Road Coefficient (mu)

FIGURE 33


Ford E-250 - Unladen
Adhesion Utilization
Ideal
Single Axle Projection
R
F
F/N (mu)
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
Deceleration (g)

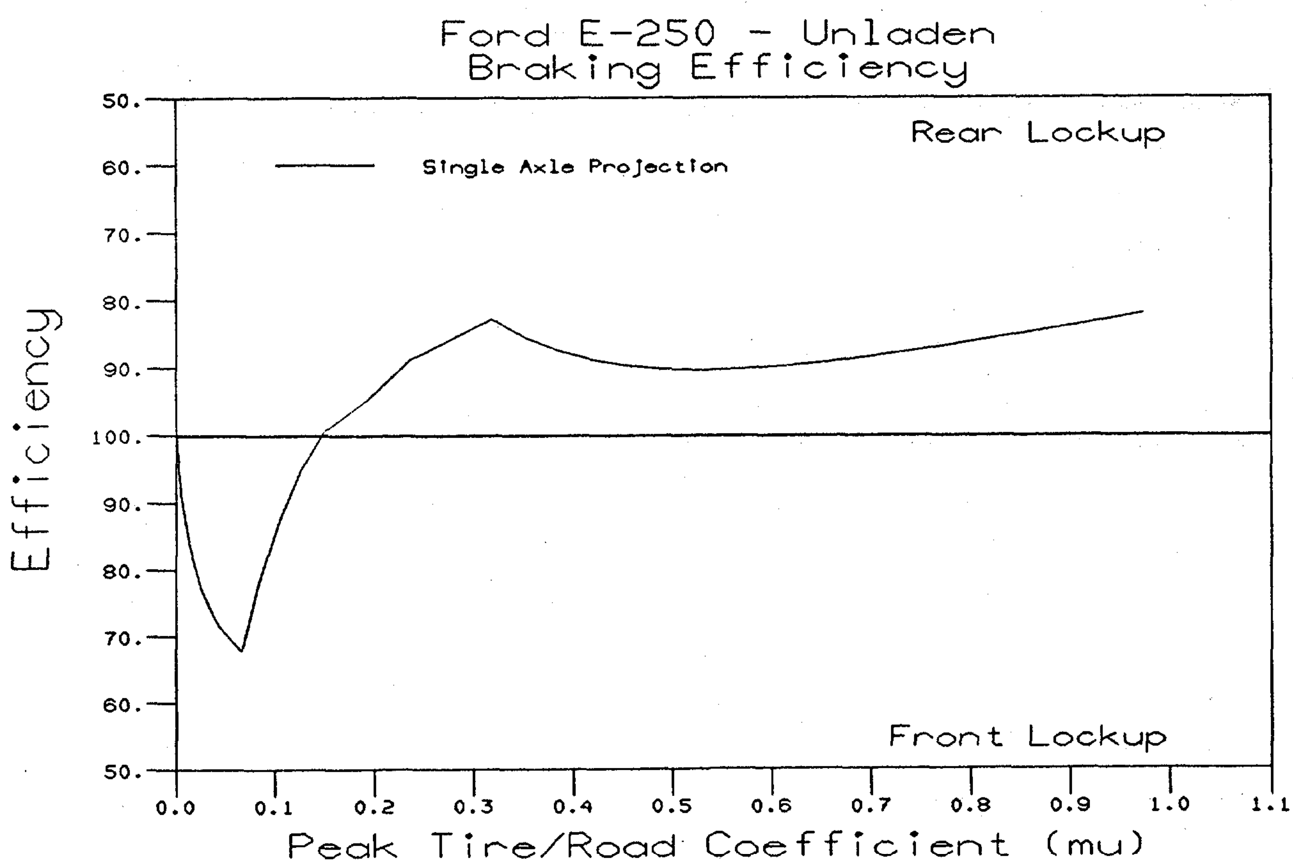

Ford E-250 - Unladen
Braking Efficiency
Rear Lockup
Single Axle Projection
Front Lockup
Efficiency
50.
60.
70.
80.
90.
100.
90.
80.
70.
60.
50.
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
Peak Tire/Road Coefficient (mu)

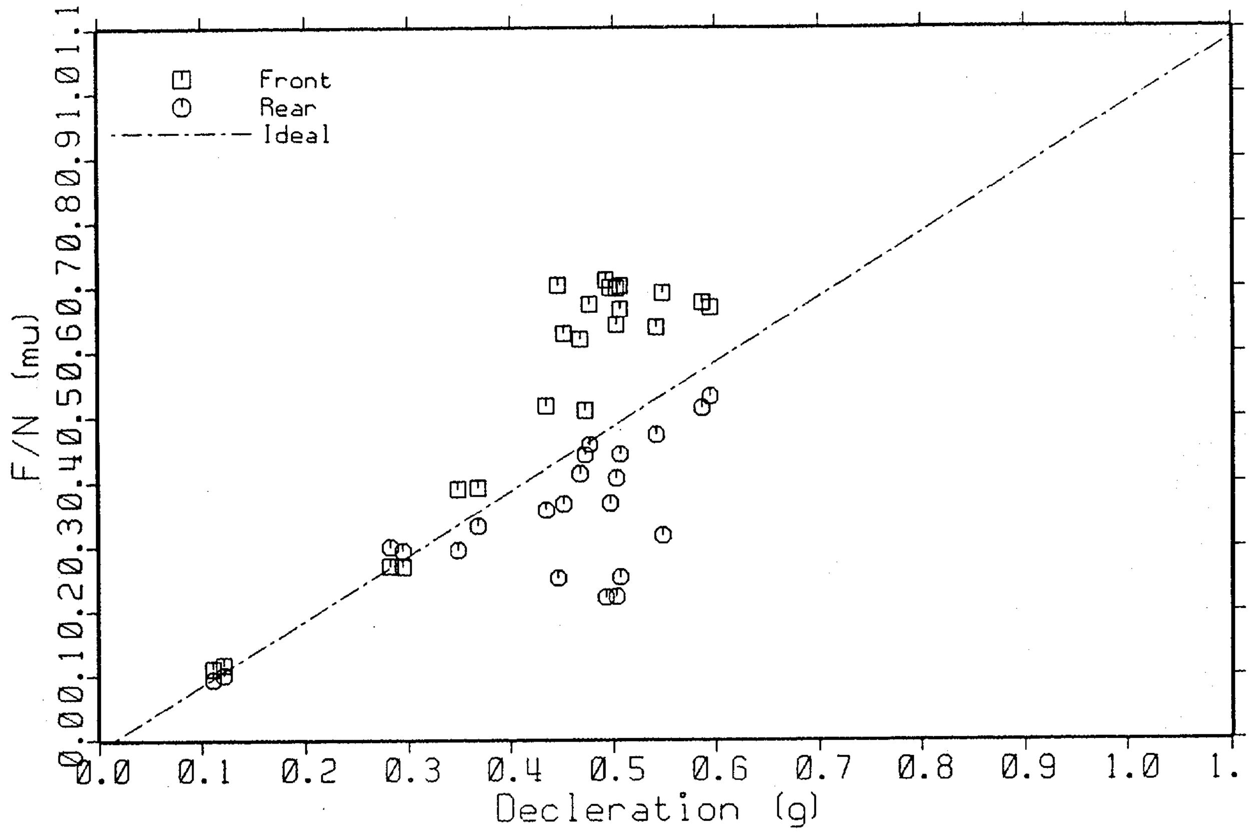
FIGURE 34

predicted to be rear brake biased for most values of mu with fairly high braking efficiency.

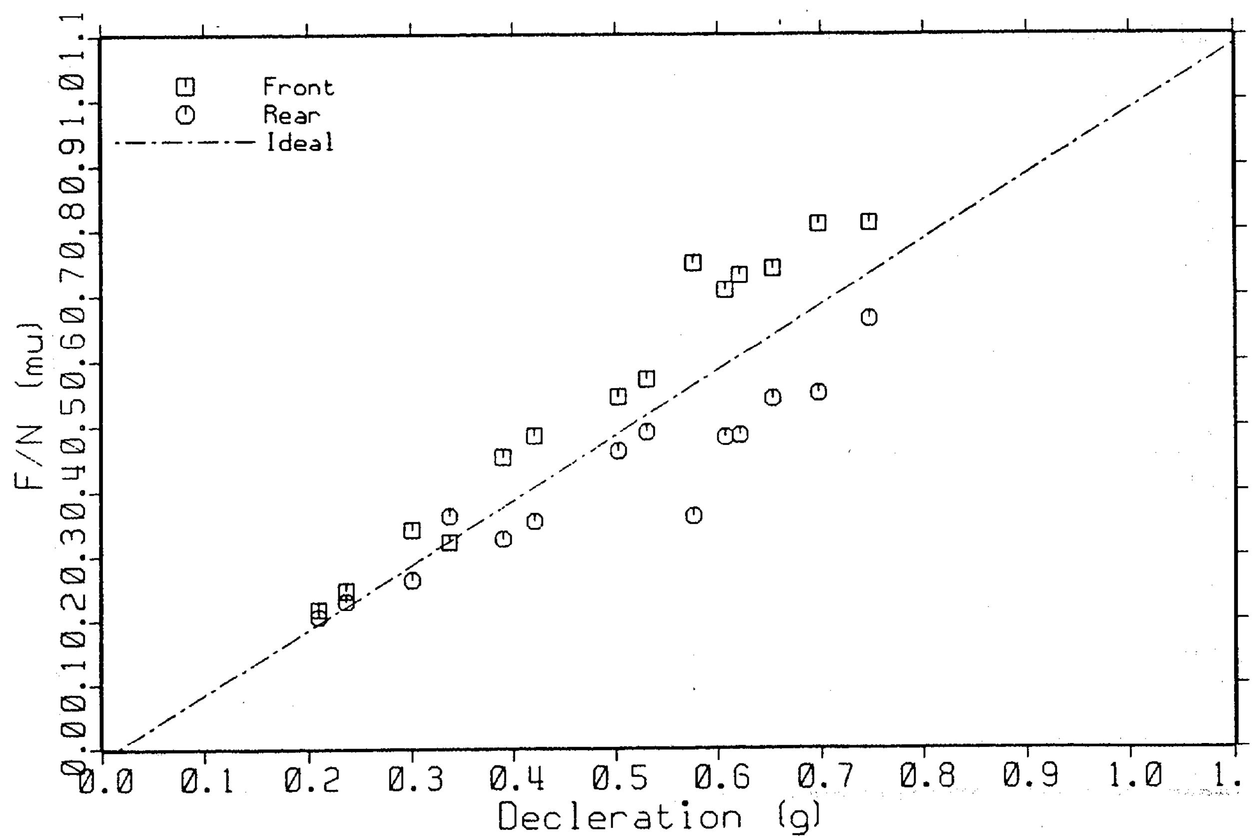
The Nissan truck was equipped with a deceleration sensing proportioning valve. In order to make a smooth projection of the brake balance for this vehicle, a number of snubs were made at various deceleration levels in both the laden and unladen condition while measuring the front and rear brake pressures. These measurements showed a great deal of scatter of the proportioning characteristics as a function of deceleration, hence, no smooth projection of brake balance could be made. Figure 35 shows the brake balance for each of the snubs made in the laden condition and also the results of the RTP tests. The unladen results are shown in Figure 36. For both loads, both methods agree that the vehicle is front brake biased and the trends of the relative amount of front bias are similar.

The Chevrolet S-10 brake balance results are shown in Figure 37 for the laden condition and Figure 38 for the unladen condition. The RTP test on this vehicle was only run immediately after the single axle test. For both loads, the vehicle is predicted to be front brake biased. The RTP and single axle methods agree reasonably well with the RTP predicting balance slightly closer to ideal in the unladen condition than the single axle test.

The results of the Ford Ranger tests are shown in Figure 39 for the laden condition and Figure 40 for the unladen condition. This vehicle had a conventional brake system with no proportioning valve. In the laden condition, the two methods agree reasonably well, predicting front brake bias up to a peak mu value of approximately 0.65. In the unladen condition, the single axle test predicted that the vehicle would switch from front biased to rear biased at approximately 0.32. The RTP tests for this vehicle showed some scatter, probably due to conditioning of the brakes, and so it is difficult to make precise predictions, however, it would appear that the RTP prediction of the crossover point would be slightly higher.



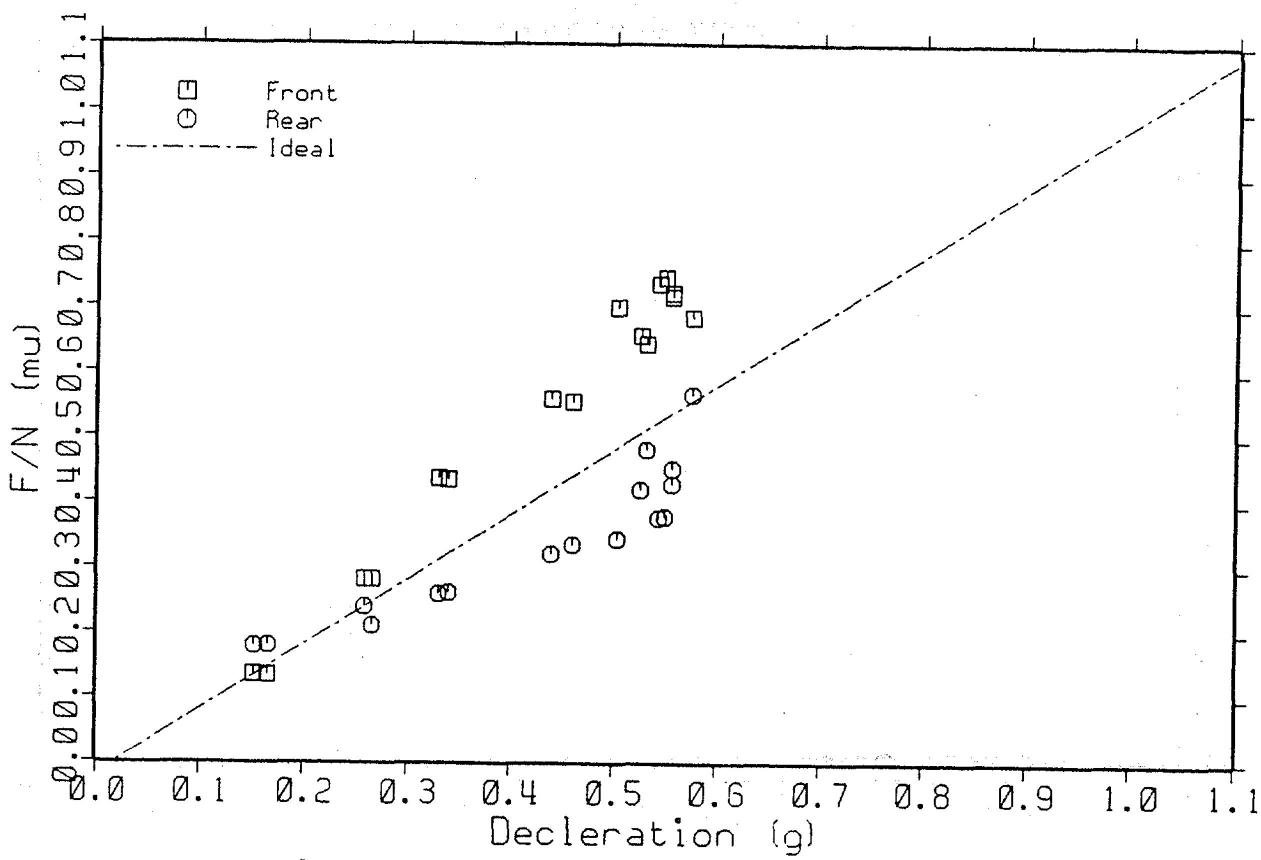
Nissan Laden - Single Axle



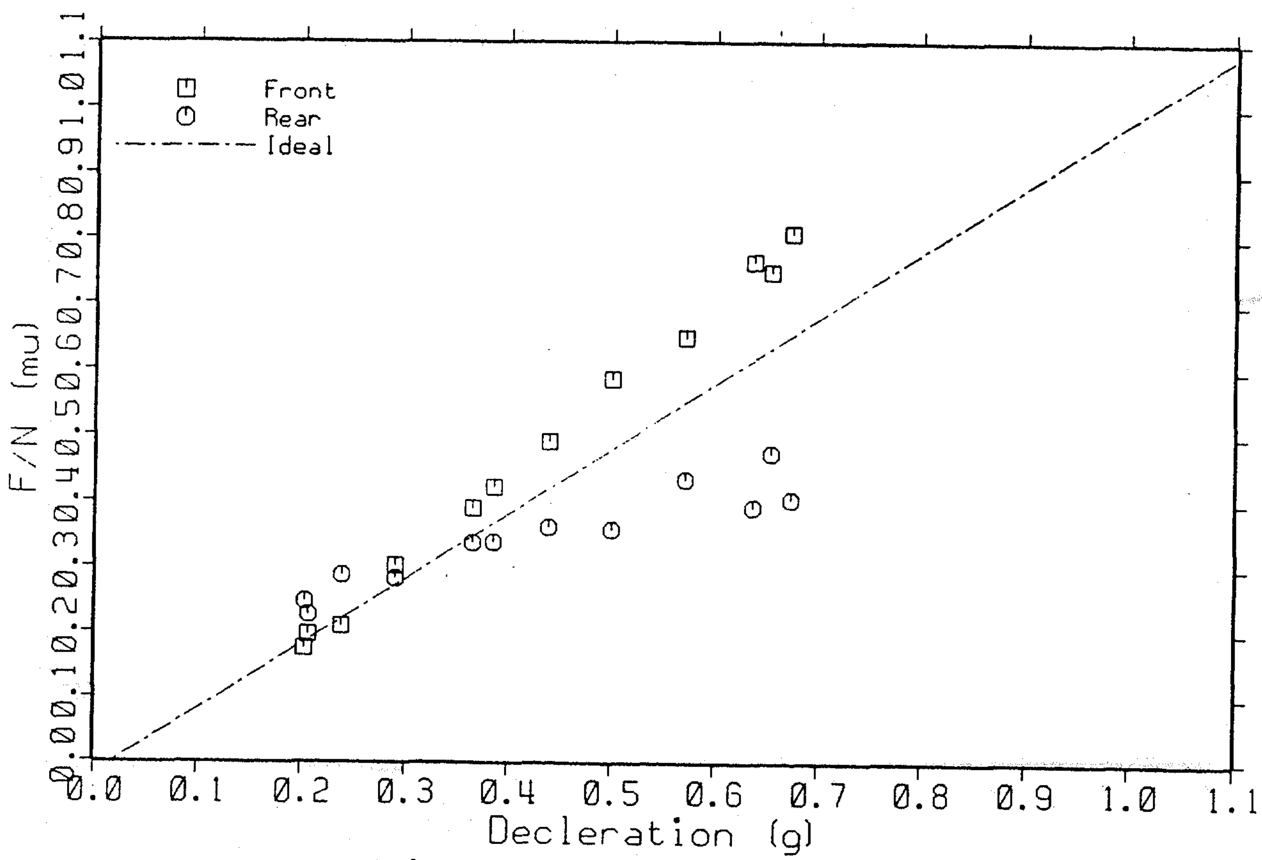
Nissan Laden - RTP

FIGURE 35

15-DEC-87 13:31

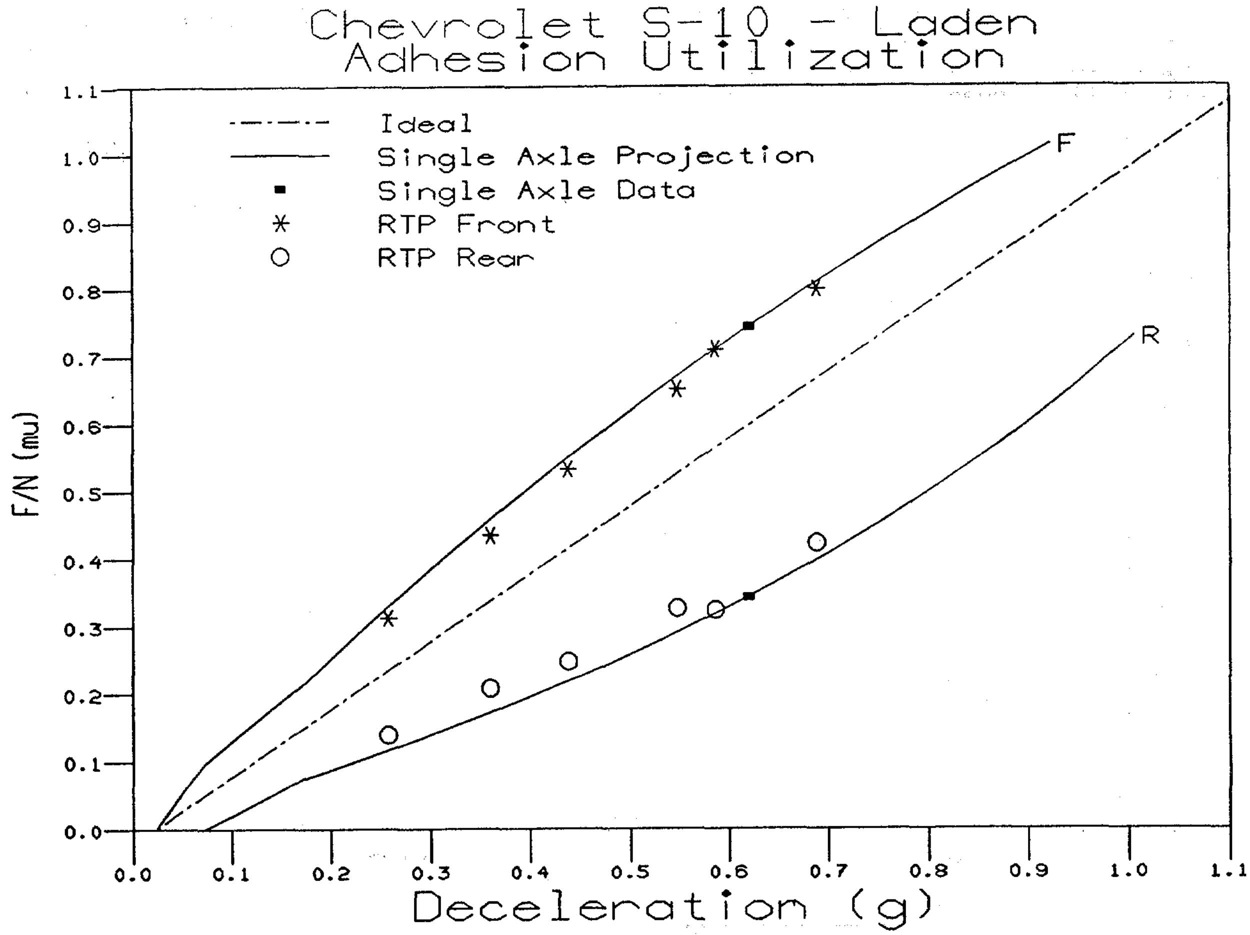


Nissan Unladen - Single Axle

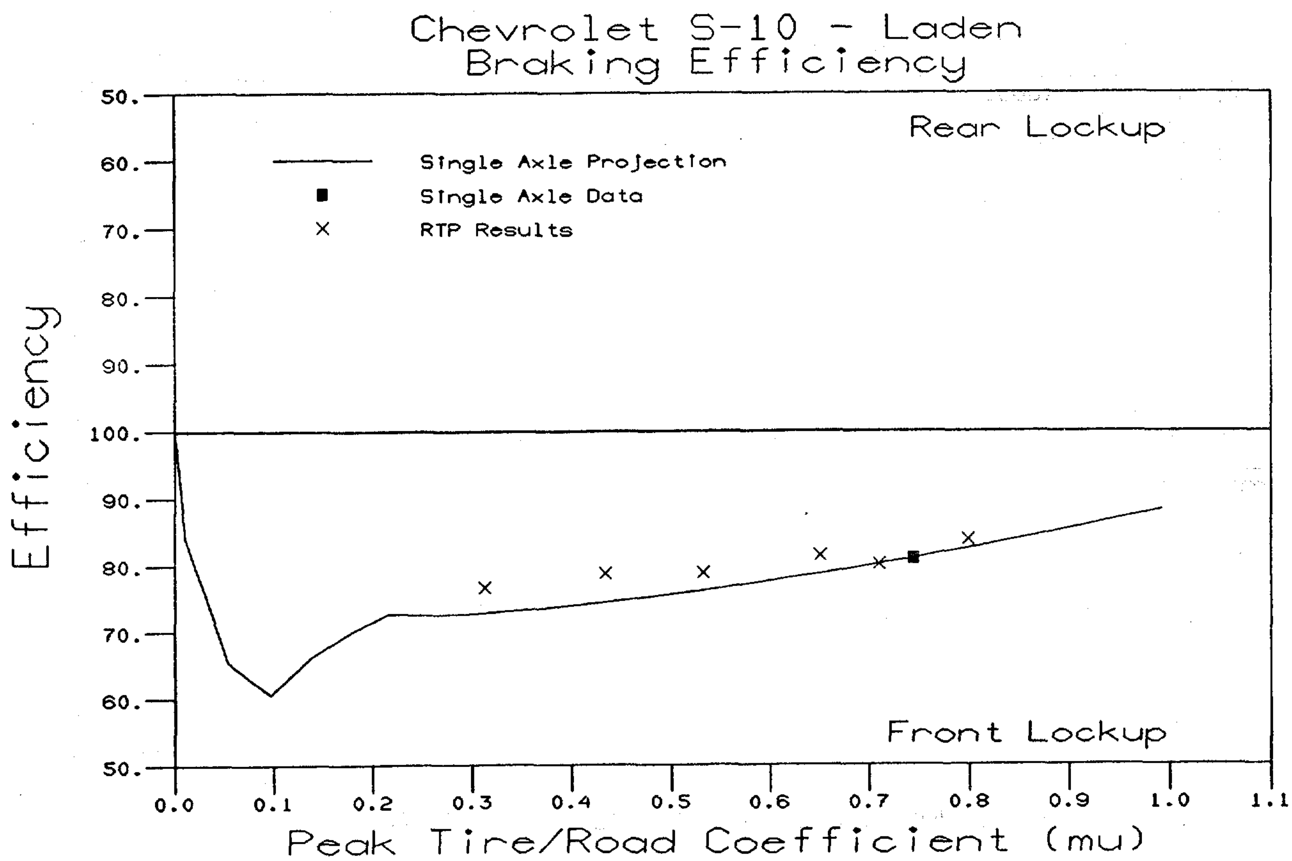


Nissan Unladen - RTP

FIGURE 36

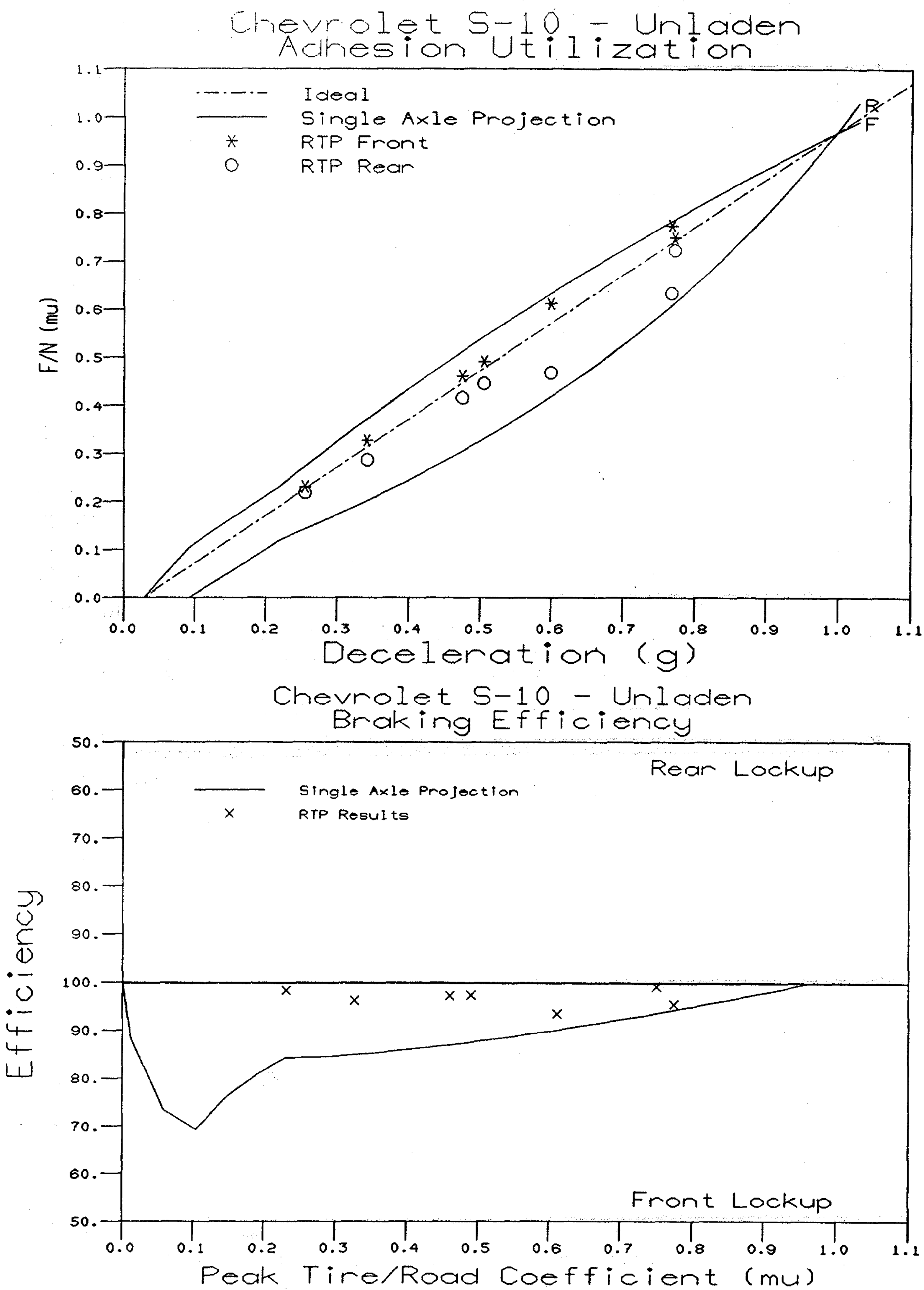


Chevrolet S-10 - Laden
Adhesion Utilization
Ideal
Single Axle Projection
Single Axle Data
RTP Front
RTP Rear
F
R
F/N (mu)
Deceleration (g)



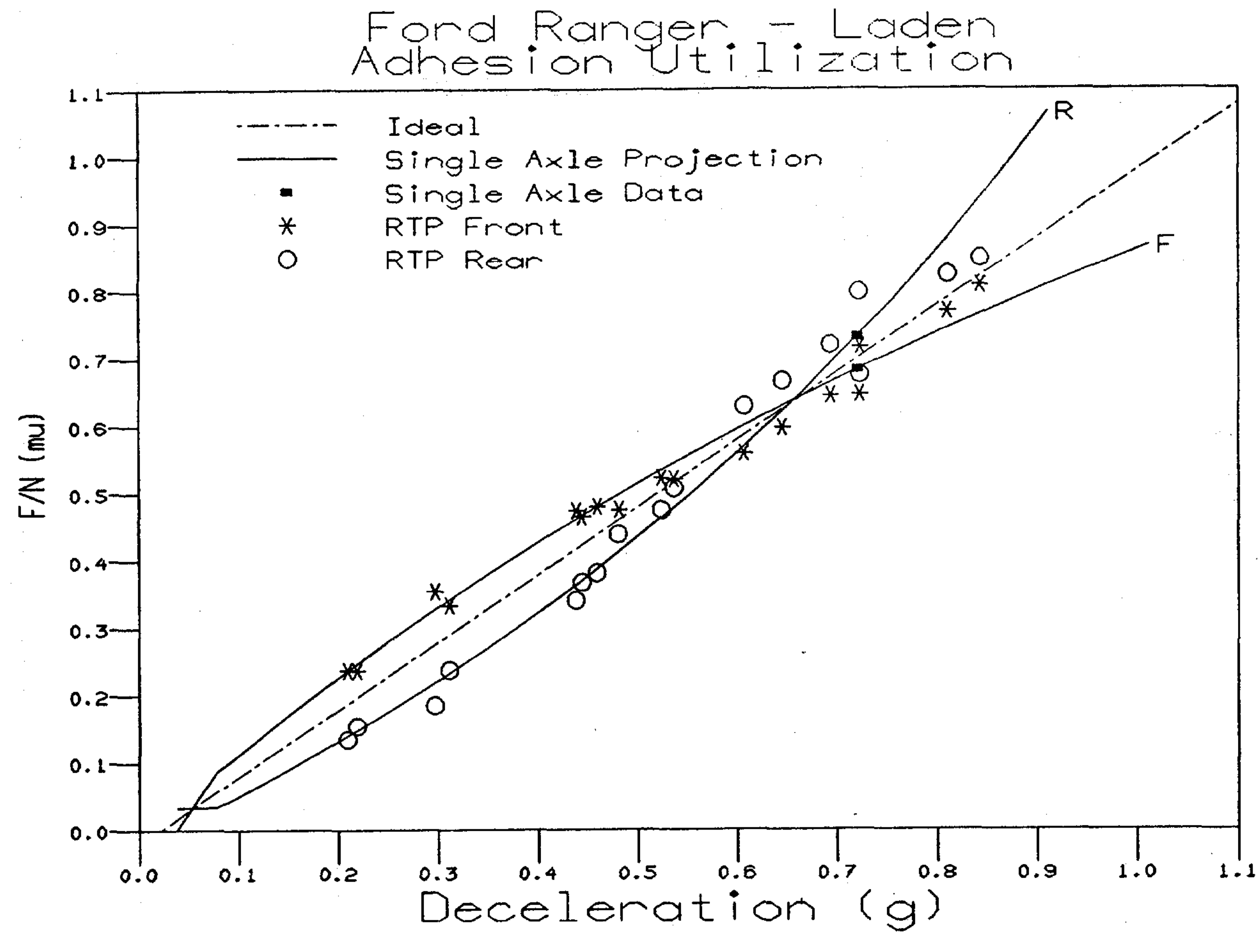
Chevrolet S-10 - Laden
Braking Efficiency
Rear Lockup
Single Axle Projection
Single Axle Data
RTP Results
Front Lockup
Efficiency
Peak Tire/Road Coefficient (mu)

FIGURE 37

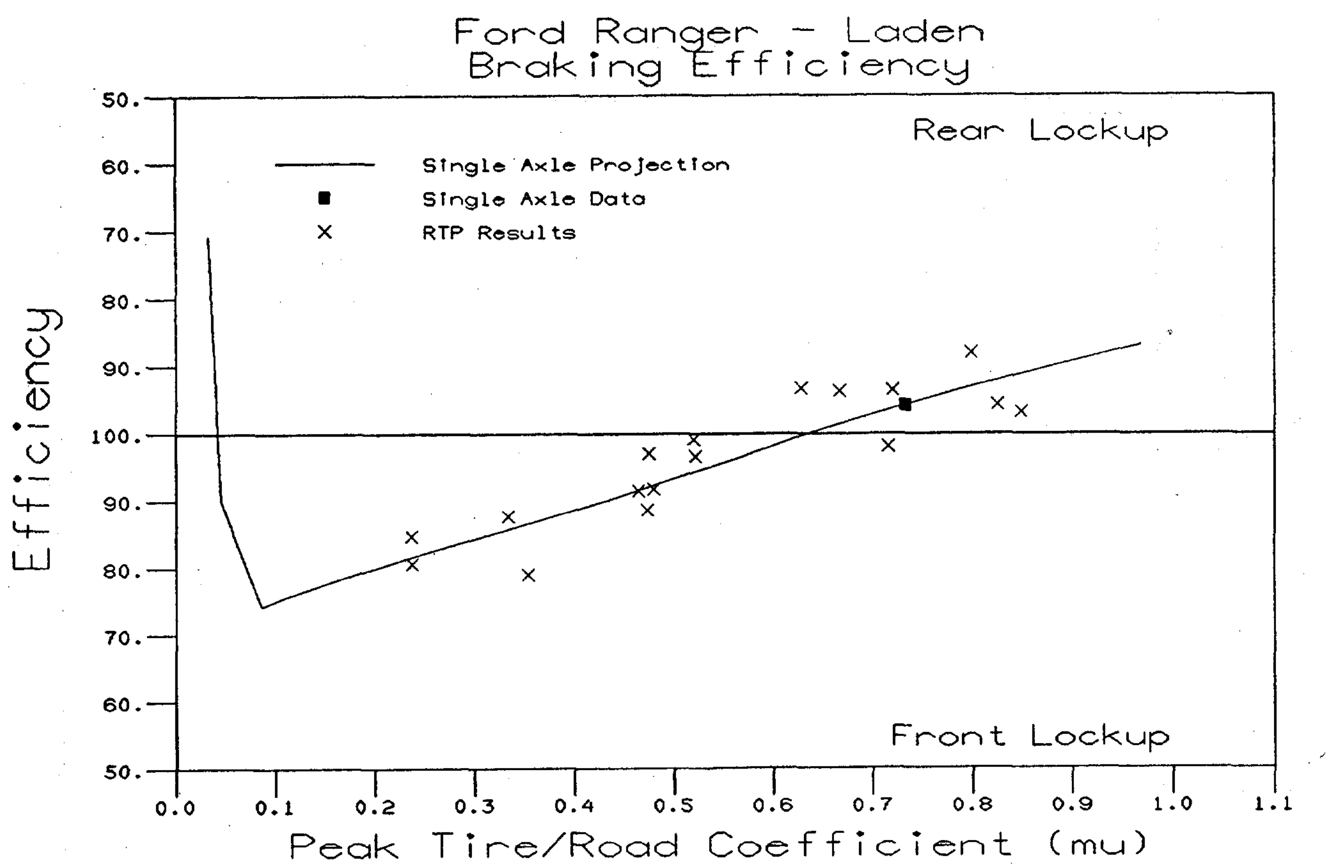


Chevrolet S-10 - Unladen
Adhesion Utilization
Ideal
Single Axle Projection
RTP Front
RTP Rear
R
F
F/N (mu)
Deceleration (g)
Chevrolet S-10 - Unladen
Braking Efficiency
Rear Lockup
Single Axle Projection
RTP Results
Front Lockup
Efficiency
Peak Tire/Road Coefficient (mu)

FIGURE 38

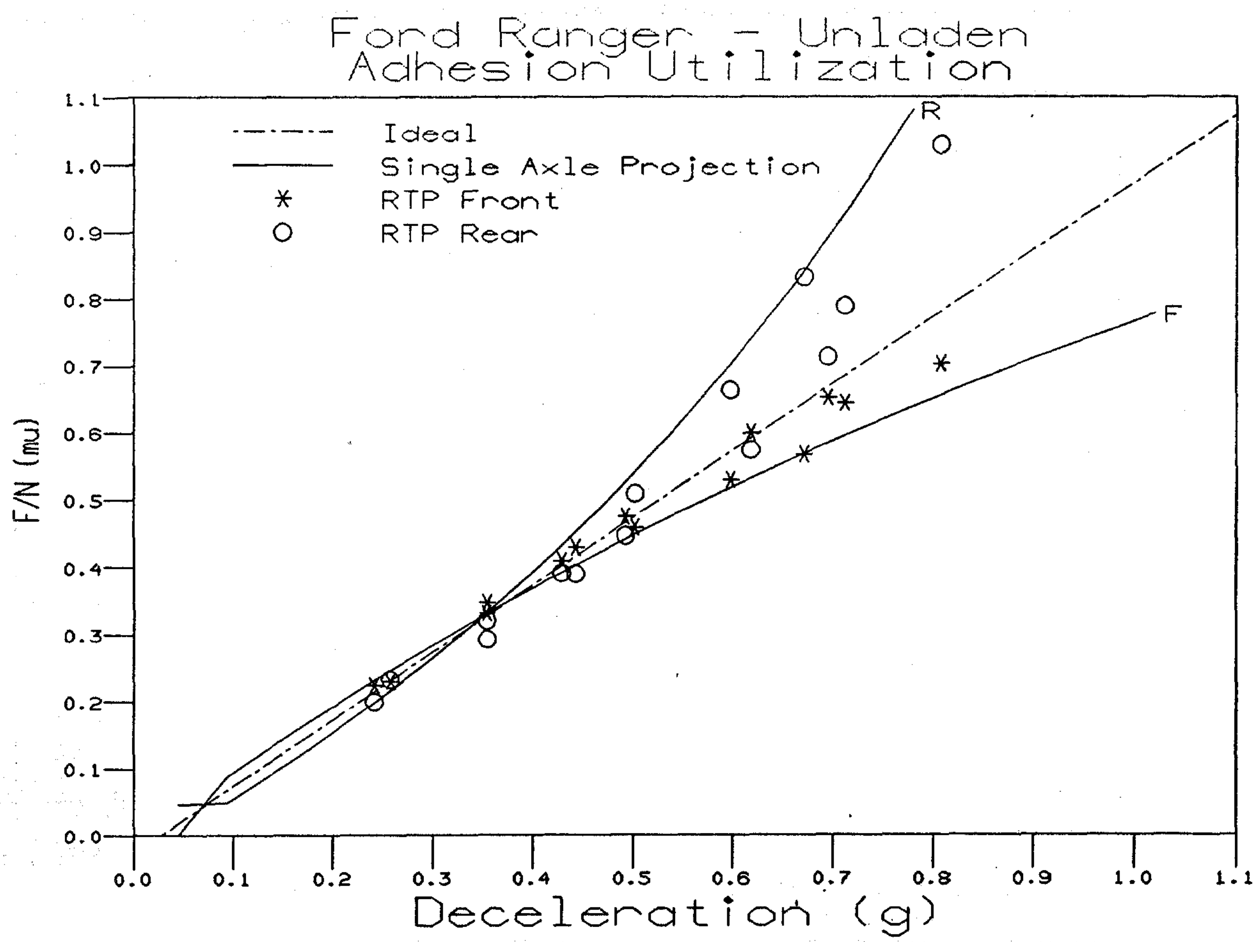


Ford Ranger - Laden
Adhesion Utilization
Ideal
Single Axle Projection
Single Axle Data
RTP Front
RTP Rear
R
F
F/N (mu)
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
Deceleration (g)

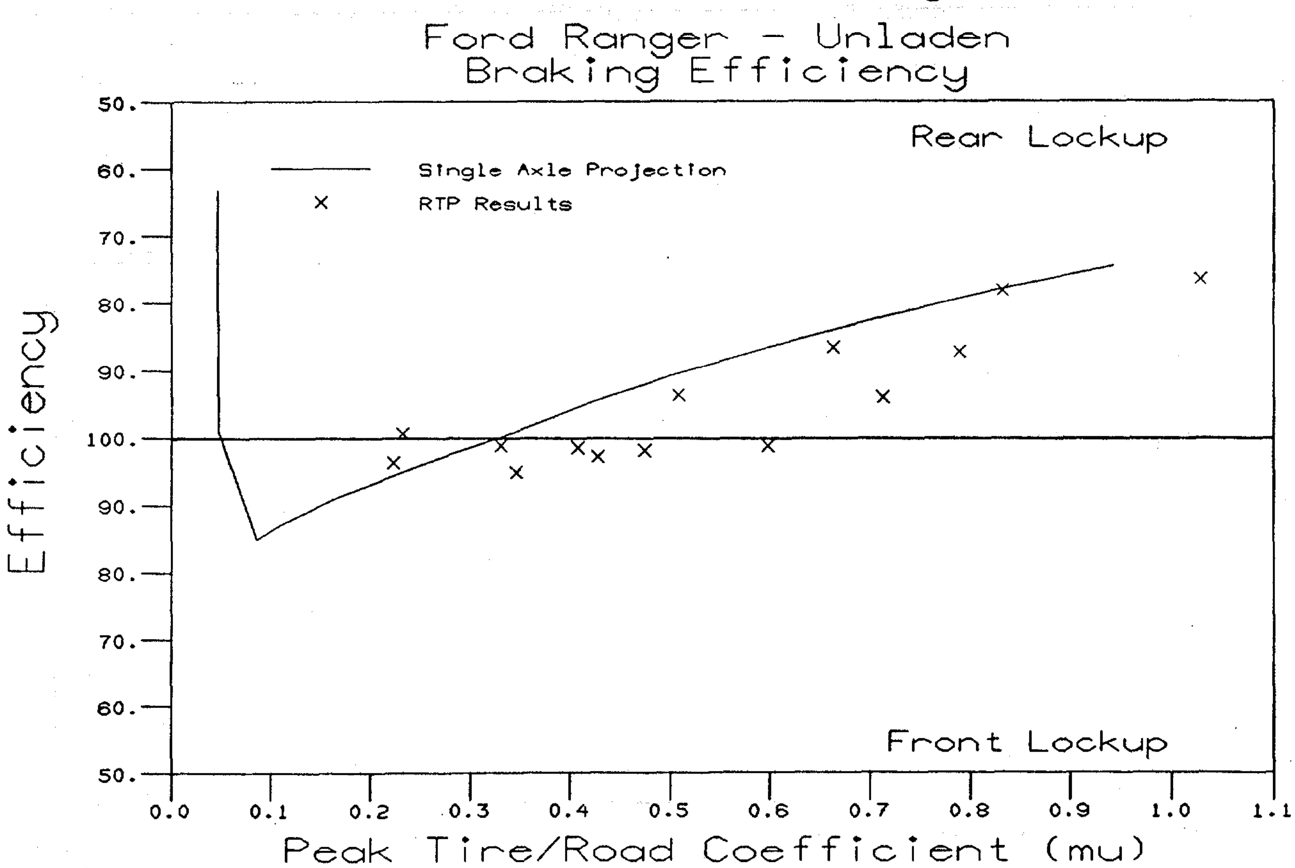


Ford Ranger - Laden
Braking Efficiency
Rear Lockup
Single Axle Projection
Single Axle Data
RTP Results
Front Lockup
Efficiency
50.
60.
70.
80.
90.
100.
90.
80.
70.
60.
50.
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
Peak Tire/Road Coefficient (mu)

FIGURE 39



Ford Ranger - Unladen
Adhesion Utilization
Ideal
Single Axle Projection
RTP Front
RTP Rear
R
F
F/N (mu)
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Deceleration (g)



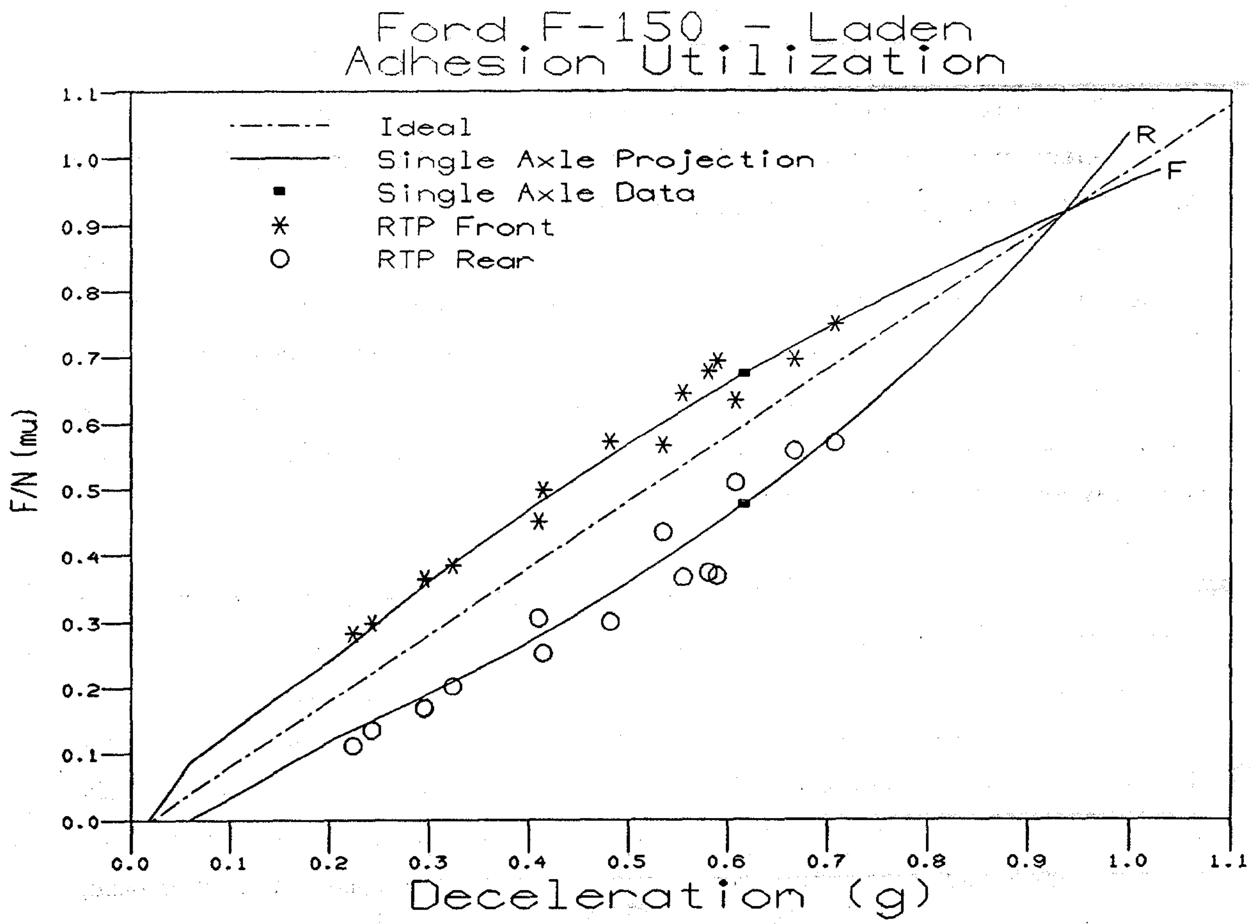
Ford Ranger - Unladen
Braking Efficiency
Rear Lockup
Single Axle Projection
RTP Results
Front Lockup
Efficiency
50.
60.
70.
80.
90.
100.
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
Peak Tire/Road Coefficient (mu)

FIGURE 40

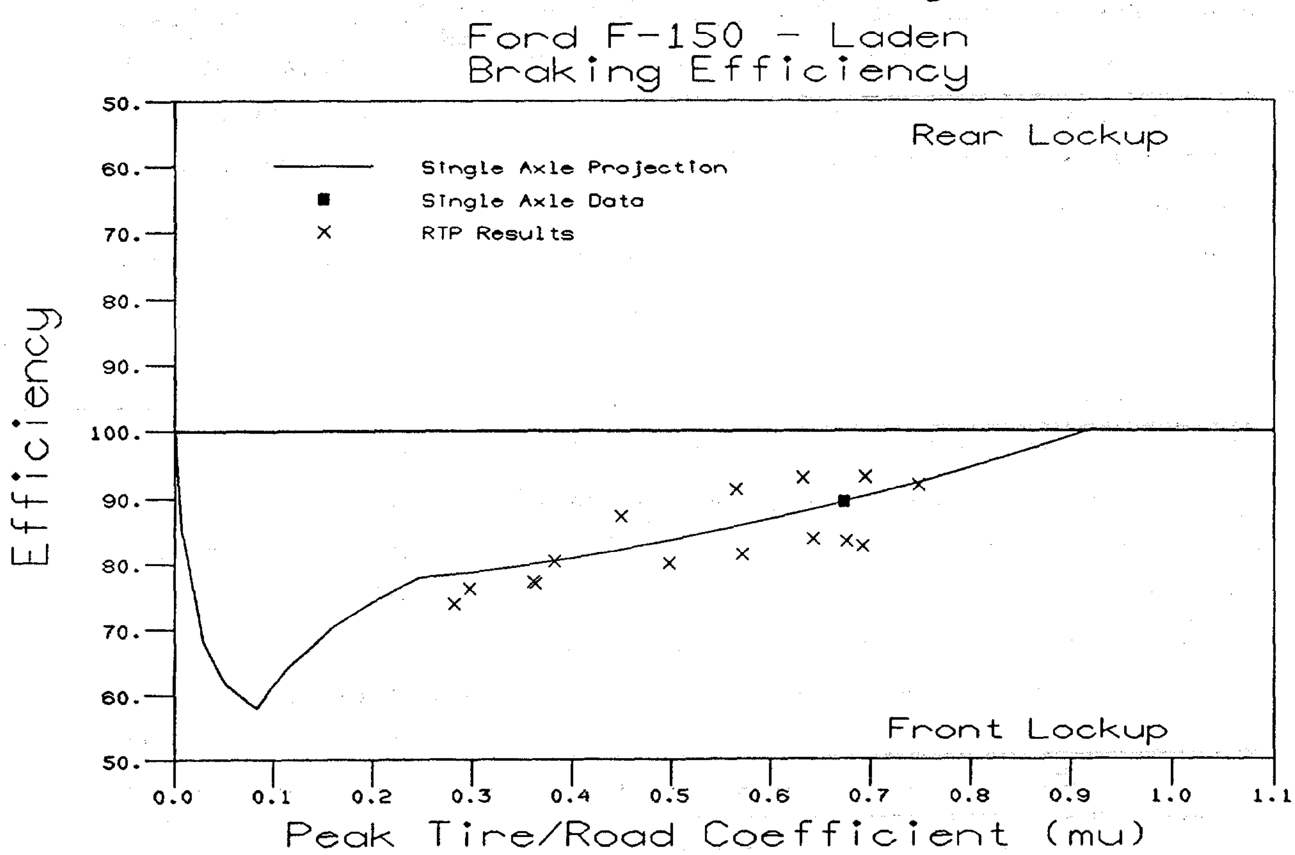
The Ford F-150 was equipped with an antilock system on the rear axle which was disconnected for these tests. The laden brake balance for this vehicle is shown in Figure 41. The vehicle is predicted to be front brake biased up to a high value of mu, hence, the rear antilock would not be used. In this load configuration, the RTP and the single axle methods agree quite well. In the unladen condition, shown in Figure 42, the single axle test predicts that the vehicle will become rear biased above a peak mu value of approximately 0.4. An RTP test was not run on this vehicle in the unladen configuration.

The Chevrolet C-1500 was also equipped with a rear antilock system which was disconnected for these tests. The brake balance test results are shown in Figure 43 for the laden condition and Figure 44 for the unladen condition. With the vehicle fully loaded, both test methods indicate that the vehicle would be front biased, however, the RTP shows more front brake force than does the single axle projection. In the unladen condition, the RTP again predicts more front braking than does the single axle procedure, with the RTP showing front brake bias while the single axle procedure predicts rear brake bias for peak mu values greater than approximately 0.35. It is unknown why the two methods do not agree for this vehicle, however, the RTP test run after the laden axle lock sequence agrees quite well with the laden RTP test shown here. (No RTP test was run after the unladen axle lock sequence.)

The results of the Ford F-150 4X4 brake balance tests are shown in Figures 45 and 46. In the laden condition, the vehicle is front brake biased up to a peak mu value of around 1.0. The single axle and RTP tests agree reasonably well. In the unladen condition, the vehicle is nearly ideally balanced in the range of peak mu's from 0.25 to 0.5. At higher peak mu values, the single axle predictions show the vehicle to be rear brake biased. The RTP tests indicate that the vehicle is front biased to slightly higher values of mu, although it is very near ideal and the agreement between the two procedures is still reasonable good.

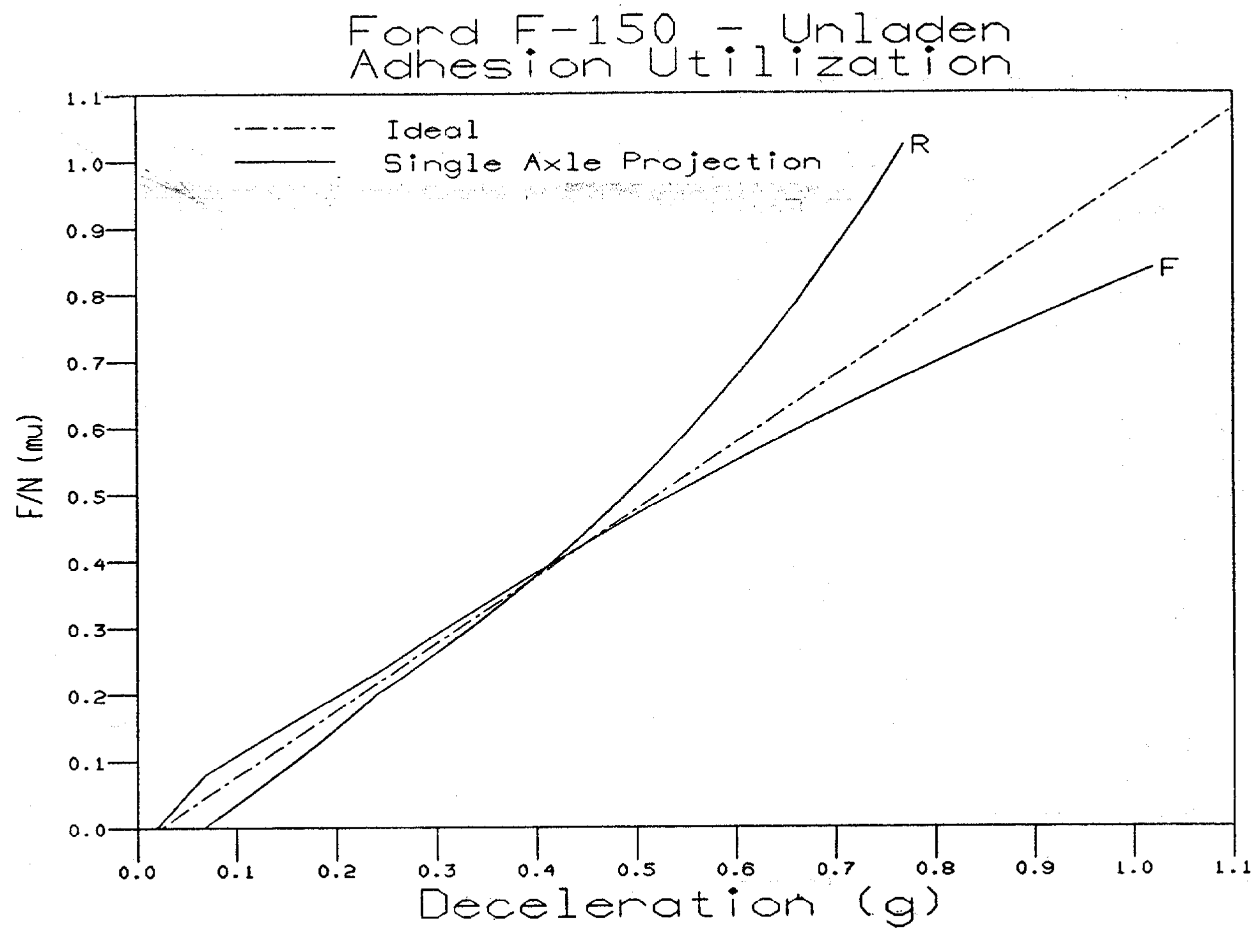


Ford F-150 - Laden
Adhesion Utilization
Ideal
Single Axle Projection
Single Axle Data
RTP Front
RTP Rear
R
F
F/N (mu)
Deceleration (g)



Ford F-150 - Laden
Braking Efficiency
Rear Lockup
Single Axle Projection
Single Axle Data
RTP Results
Front Lockup
Efficiency
Peak Tire/Road Coefficient (mu)

FIGURE 41


Ford F-150 - Unladen
Adhesion Utilization
Ideal
Single Axle Projection
R
F
F/N (mu)
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
Deceleration (g)

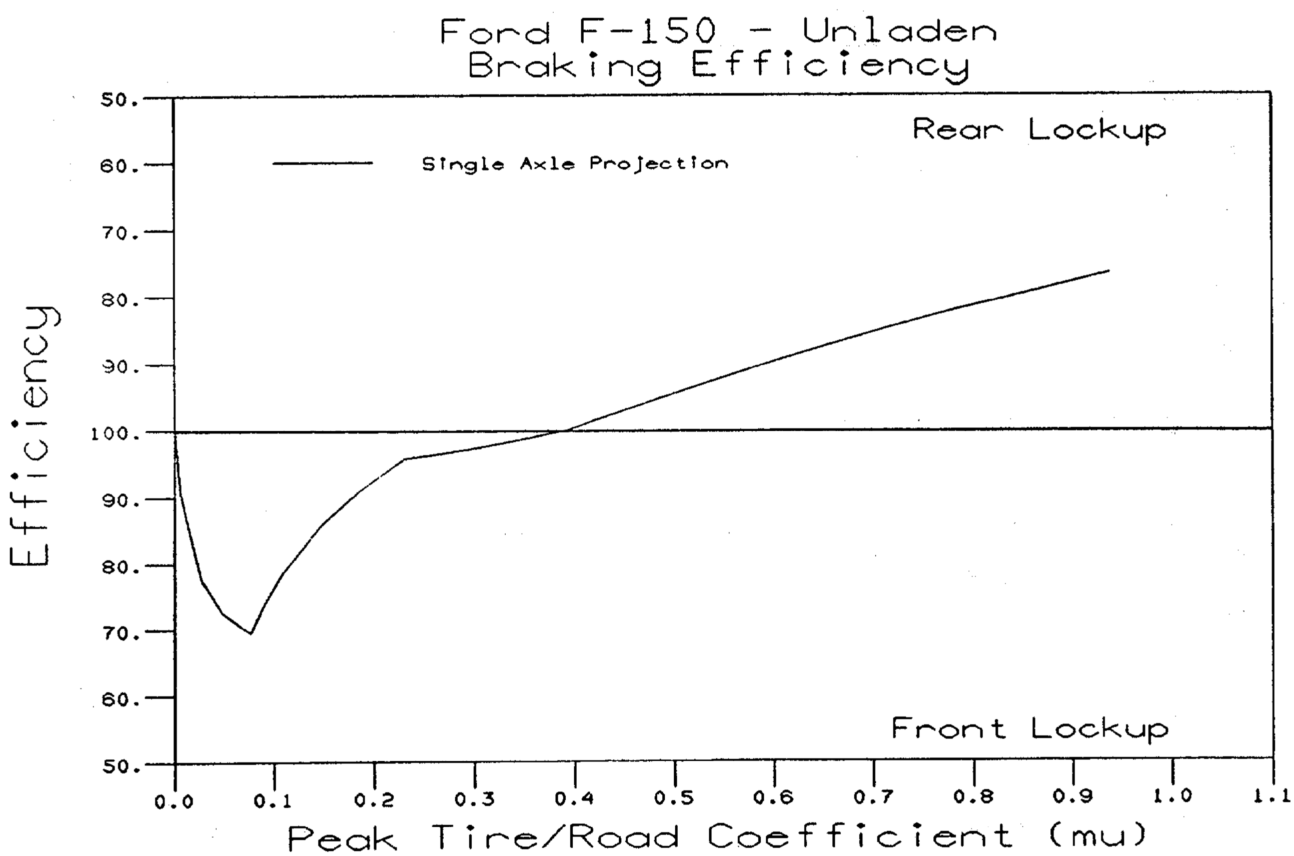
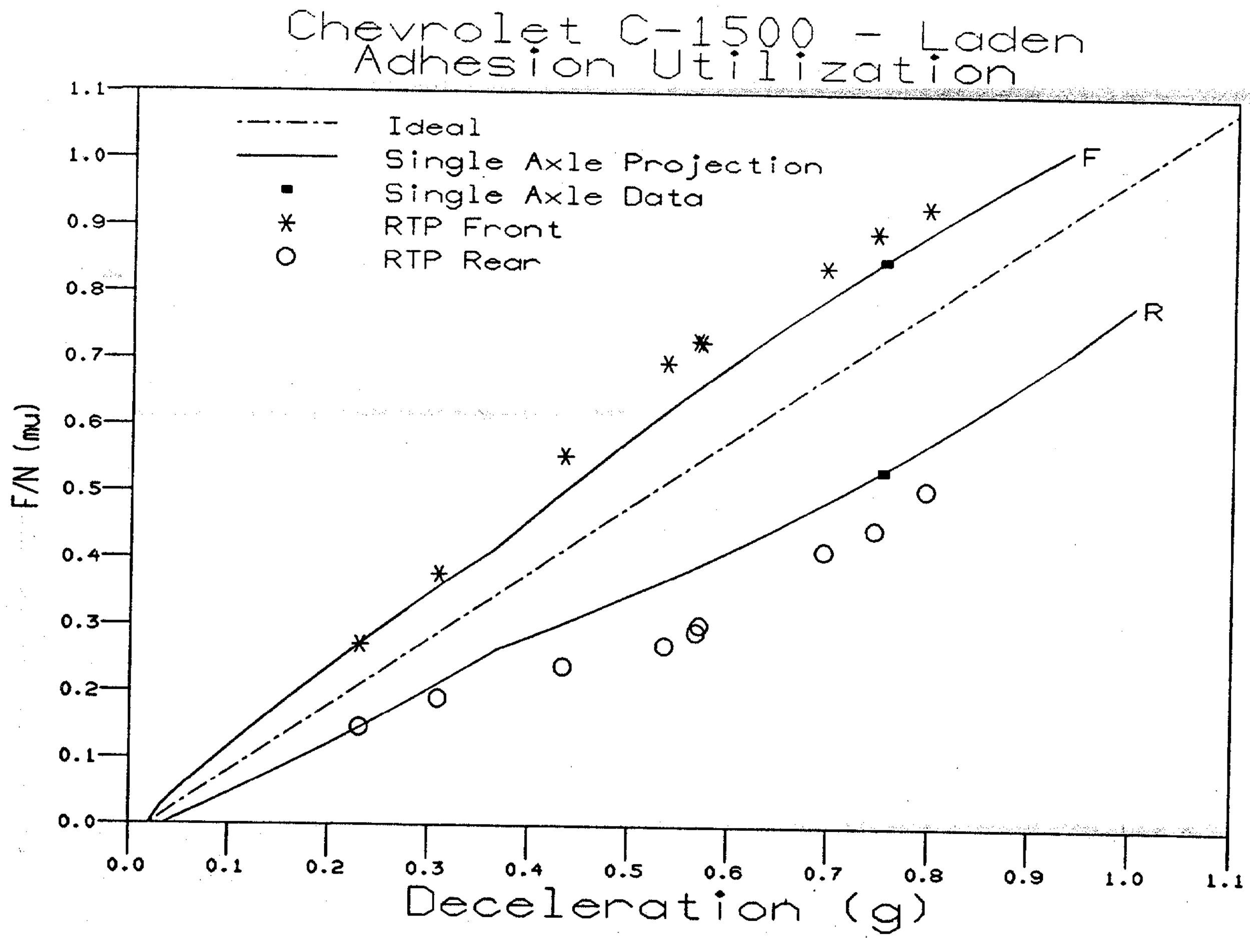

Ford F-150 - Unladen
Braking Efficiency
Rear Lockup
Single Axle Projection
Front Lockup
Efficiency
50.
60.
70.
80.
90.
100.
90.
80.
70.
60.
50.
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
Peak Tire/Road Coefficient (mu)

FIGURE 42


Chevrolet C-1500 - Laden
Adhesion Utilization
Ideal
Single Axle Projection
Single Axle Data
RTP Front
RTP Rear
F
R
F/N (mu)
Deceleration (g)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1

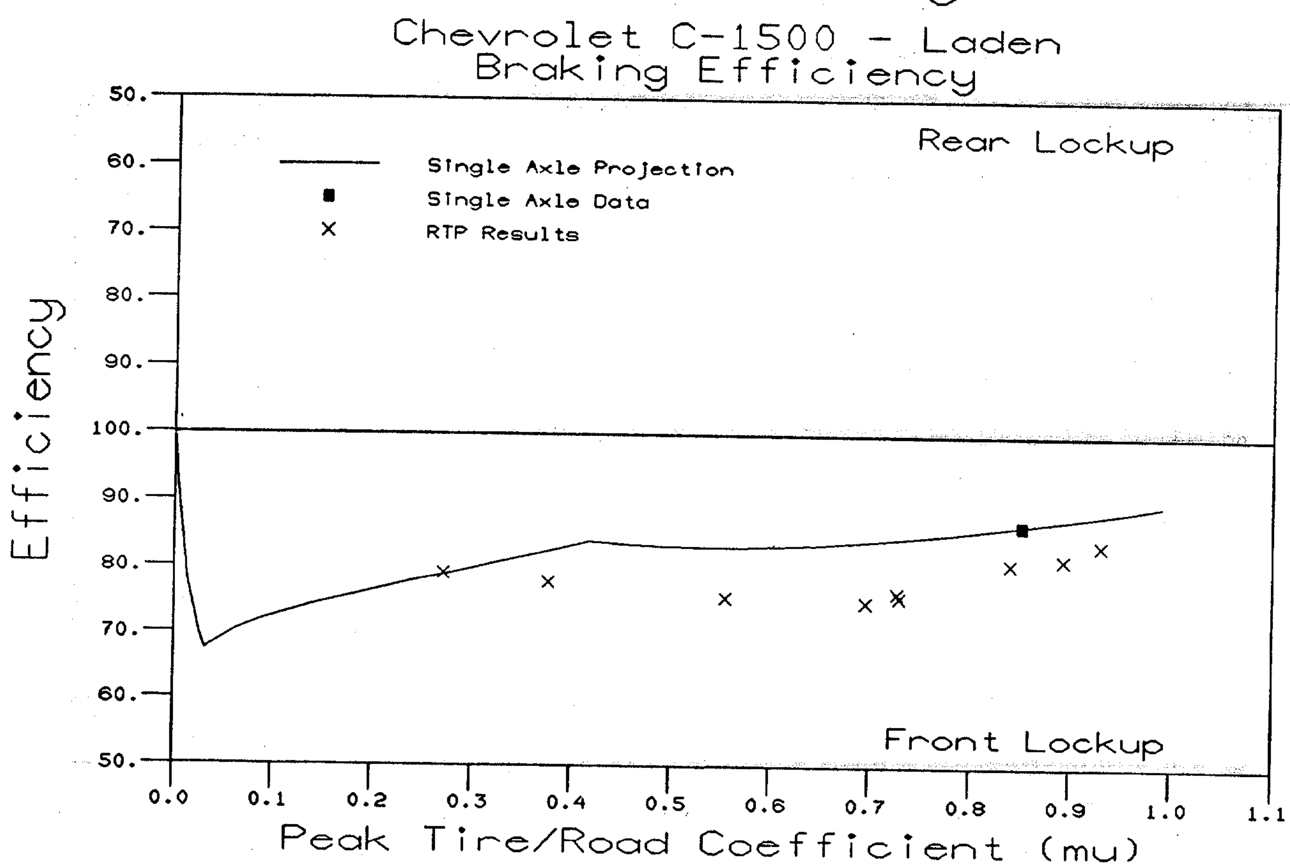

Chevrolet C-1500 - Laden
Braking Efficiency
Rear Lockup
Single Axle Projection
Single Axle Data
RTP Results
Front Lockup
Efficiency
Peak Tire/Road Coefficient (mu)
50.
60.
70.
80.
90.
100.
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1

FIGURE 43

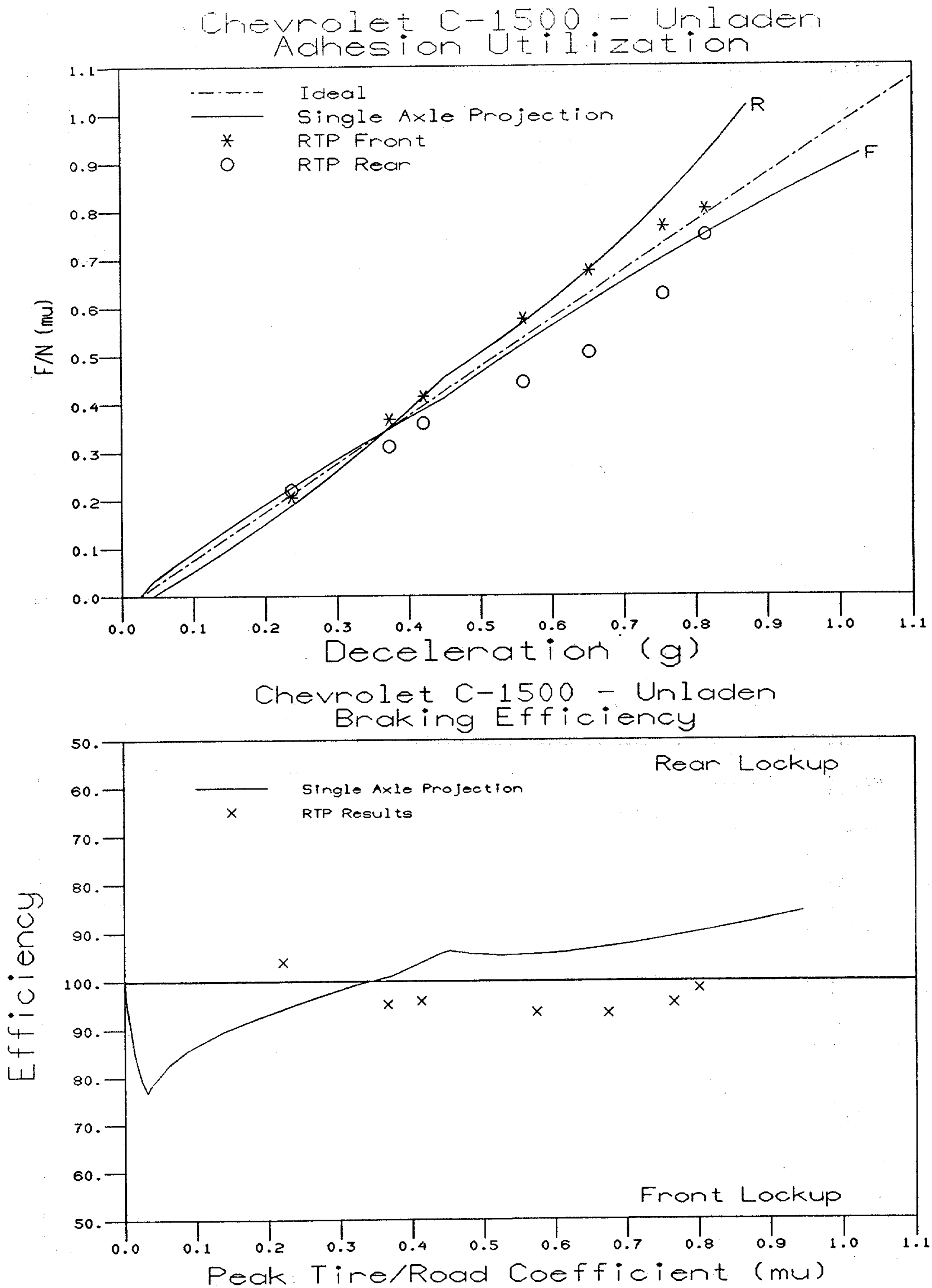
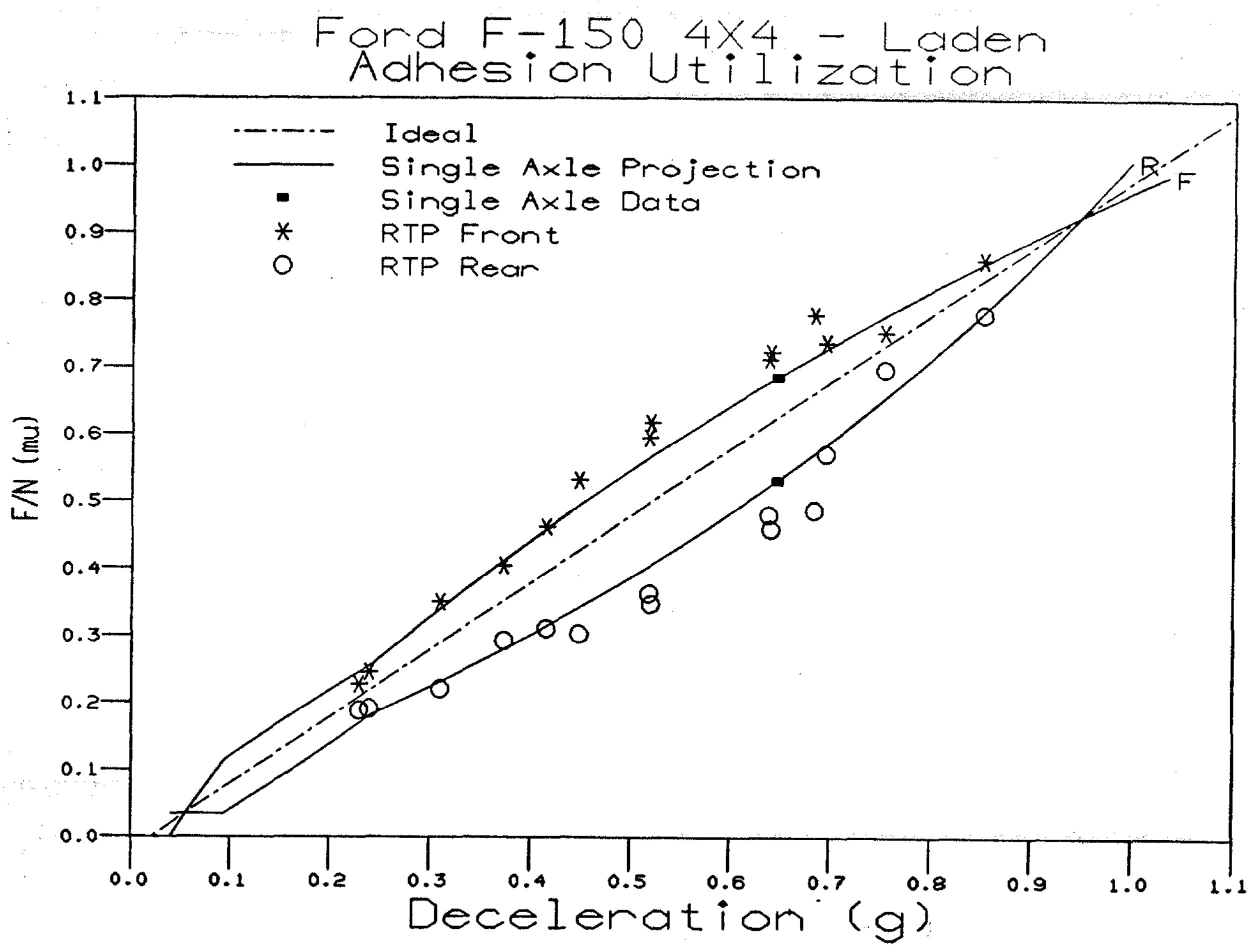

Chevrolet C-1500 - Unladen
Adhesion Utilization
Ideal
Single Axle Projection
RTP Front
RTP Rear
R
F
F/N (mu)
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
Deceleration (g)
Chevrolet C-1500 - Unladen
Braking Efficiency
Rear Lockup
Single Axle Projection
RTP Results
Front Lockup
Efficiency
50.
60.
70.
80.
90.
100.
90.
80.
70.
60.
50.
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
Peak Tire/Road Coefficient (mu)

FIGURE 44


Ford F-150 4X4 - Laden
Adhesion Utilization
Ideal
Single Axle Projection
Single Axle Data
RTP Front
RTP Rear
R
F
F/N (mu)
Deceleration (g)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1

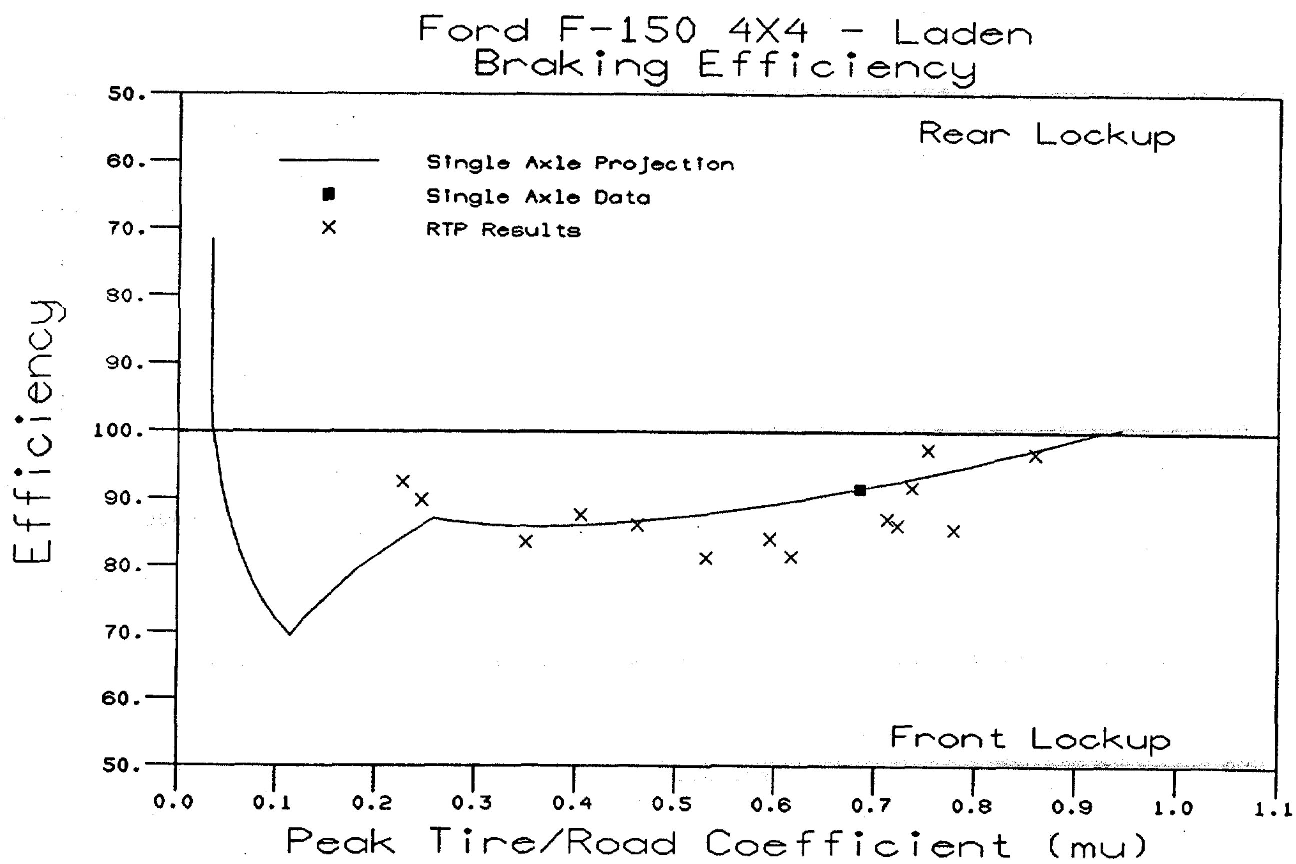
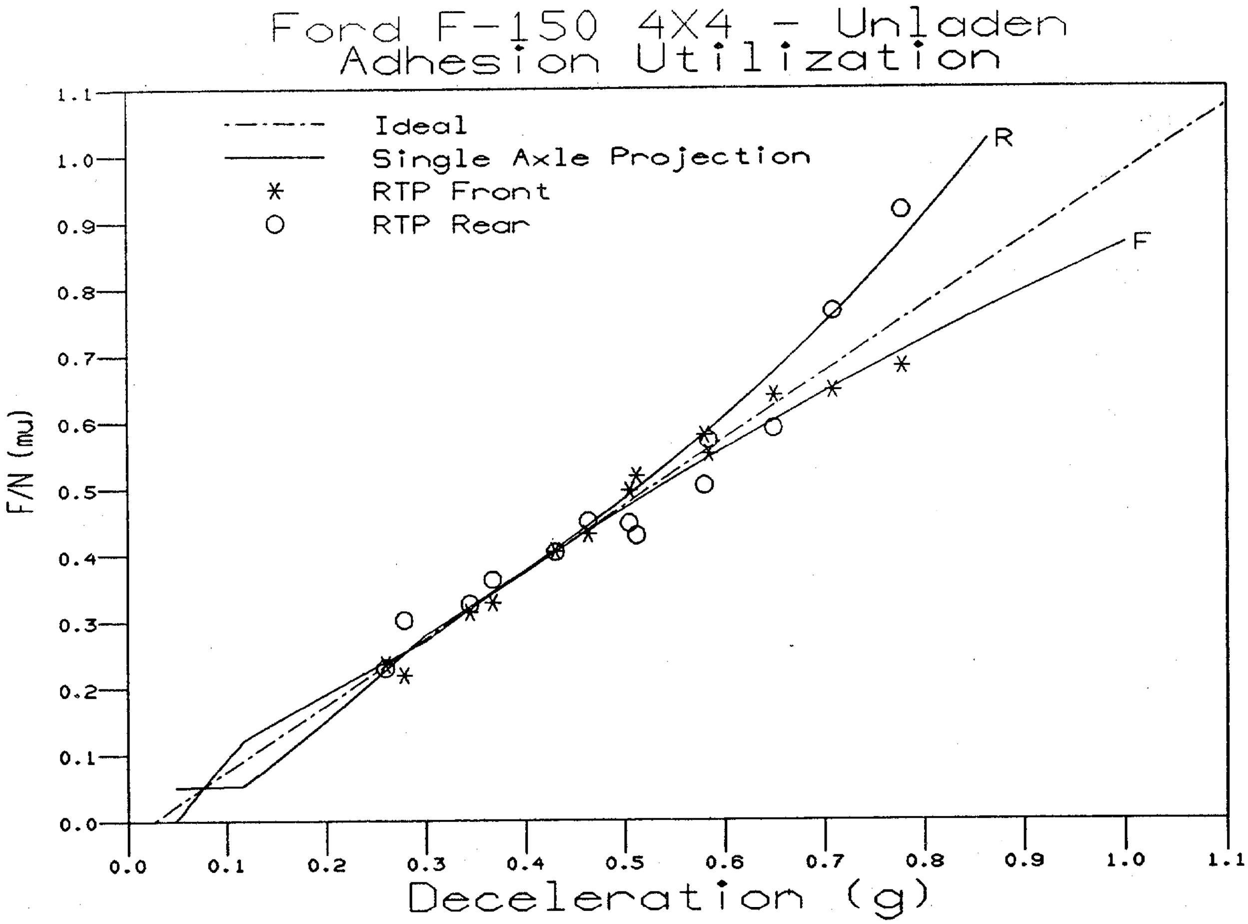

Ford F-150 4X4 - Laden
Braking Efficiency
Rear Lockup
Single Axle Projection
Single Axle Data
RTP Results
Front Lockup
Efficiency
Peak Tire/Road Coefficient (mu)
50.
60.
70.
80.
90.
100.
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1

FIGURE 45


Ford F-150 4X4 - Unladen
Adhesion Utilization
Ideal
Single Axle Projection
RTP Front
RTP Rear
R
F
F/N (mu)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
Deceleration (g)

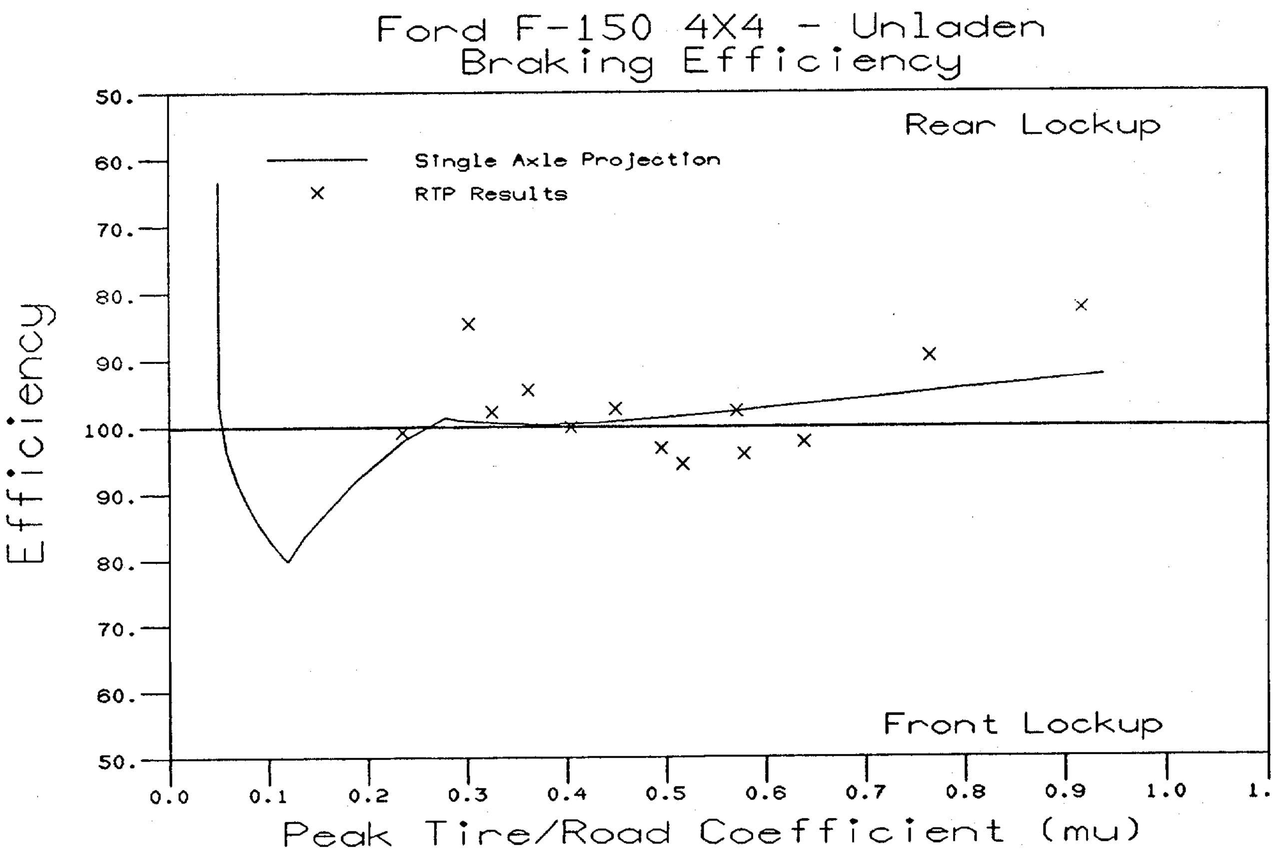

Ford F-150 4X4 - Unladen
Braking Efficiency
Rear Lockup
Single Axle Projection
RTP Results
Front Lockup
Efficiency
50.
60.
70.
80.
90.
100.
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
Peak Tire/Road Coefficient (mu)

FIGURE 46

The brake balance results for the Dodge Dakota are shown in Figure 47 in the laden condition and in Figure 48 in the unladen condition. No RTP tests were run on this vehicle. The Dakota, which had a height sensing proportioning valve, was predicted to be front brake biased in both load configurations.

The Toyota 4-Runner had a height sensing proportioning valve. The brake balance results are shown in Figures 49 and 50 for the laden and unladen cases respectively. In the laden condition, the vehicle is basically front brake bised with efficiencies above 80 percent. The single axle and the RTP show good agreement. For the unladen case, the vehicle is front biased except at mu values below approximately 0.35. The rear brake bias at the low mu's is due to the drag of the transmission acting on the rear wheels. Again, the single axle and the RTP show good agreement.

For the Jeep Cherokee, the brake balance results are shown in Figures 51 and 52 for the laden and unladen conditions respectively. In the laden condition, the vehicle is predicted to be front brake biased for the entire range of mu. The RTP tests and the single axle method give good agreement. In the unladen configuration, the tests indicate the vehicle will switch from front brake biased to rear brake biased at approximately 0.75 mu. Again, the RTP and the single axle methods agree quite well.

As a means to compare the overall brake balance of the light trucks described in this report to the passenger cars discussed in Reference 5, plots were made showing the braking efficiency of all of the vehicles of each sample on one plot. The plot showing the braking efficiency from the single axle test for 12 of the 13 vehicles in the laden configuration (the Nissan truck is not shown due to the scatter in the results discussed earlier) is shown in Figure 53. The laden brake balance for the passenger cars is shown in Figure 54. All 13 vehicles on the RTP in the laden condition are shown in Figure 55. For the unladen configuration, the single axle results for the light trucks is shown in Figure 56, the passenger car balance is shown in

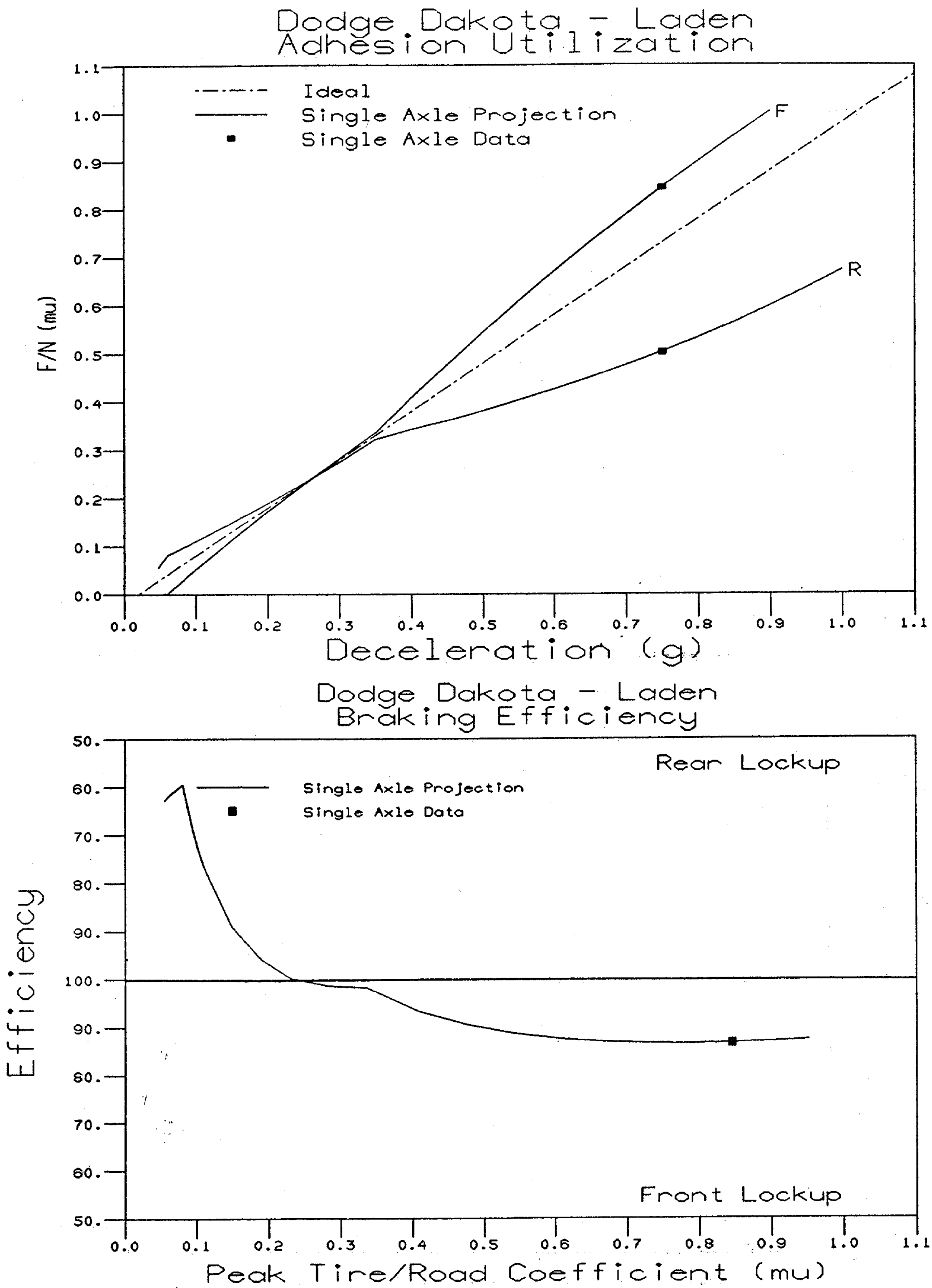
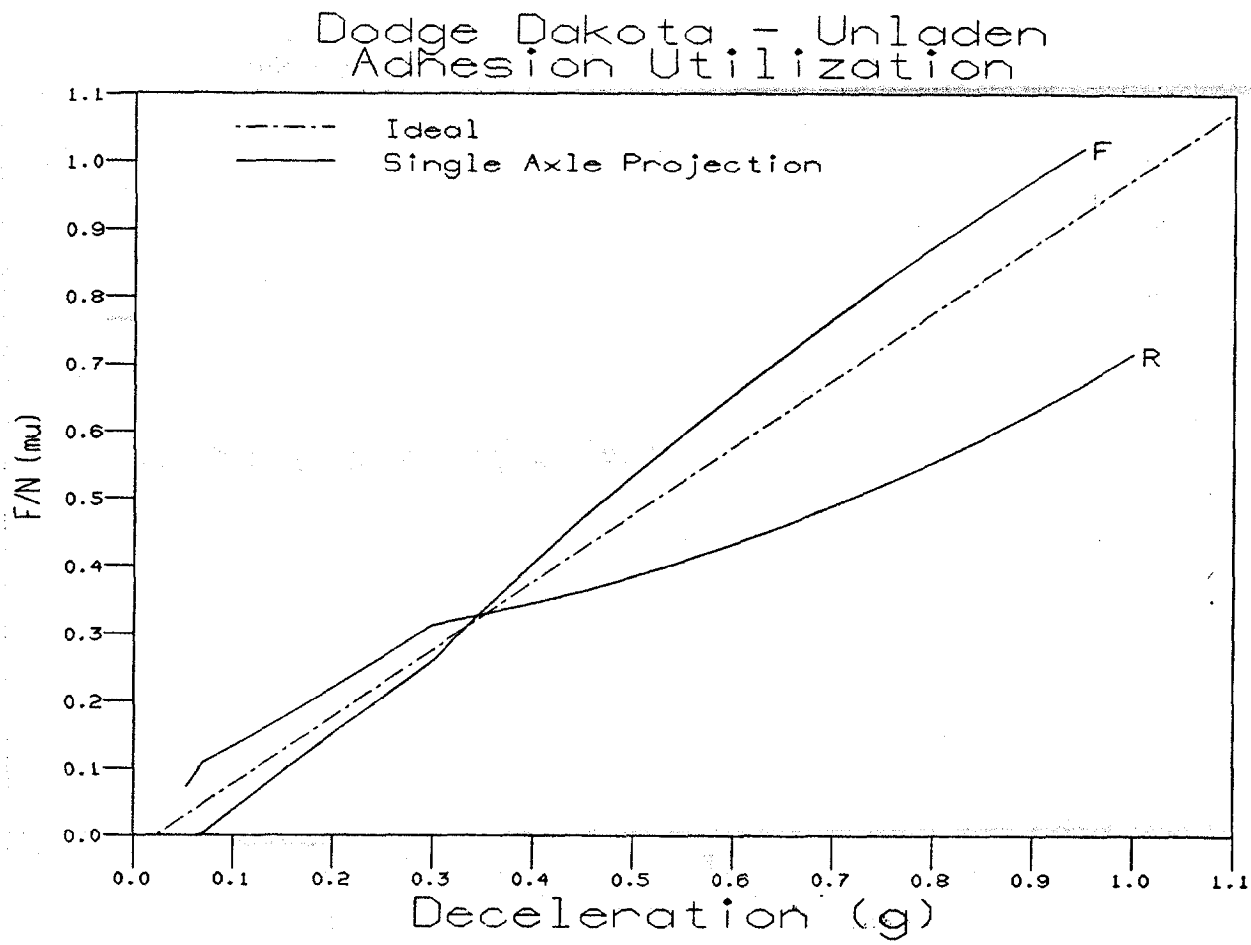

Dodge Dakota - Laden
Adhesion Utilization
Ideal
Single Axle Projection
Single Axle Data
F
R
F/N (mu)
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
Deceleration (g)
Dodge Dakota - Laden
Braking Efficiency
Rear Lockup
Single Axle Projection
Single Axle Data
Front Lockup
Efficiency
50.
60.
70.
80.
90.
100.
90.
80.
70.
60.
50.
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
Peak Tire/Road Coefficient (mu)

FIGURE 47


Dodge Dakota - Unladen
Adhesion Utilization
Ideal
Single Axle Projection
F
R
F/N (mu)
Deceleration (g)

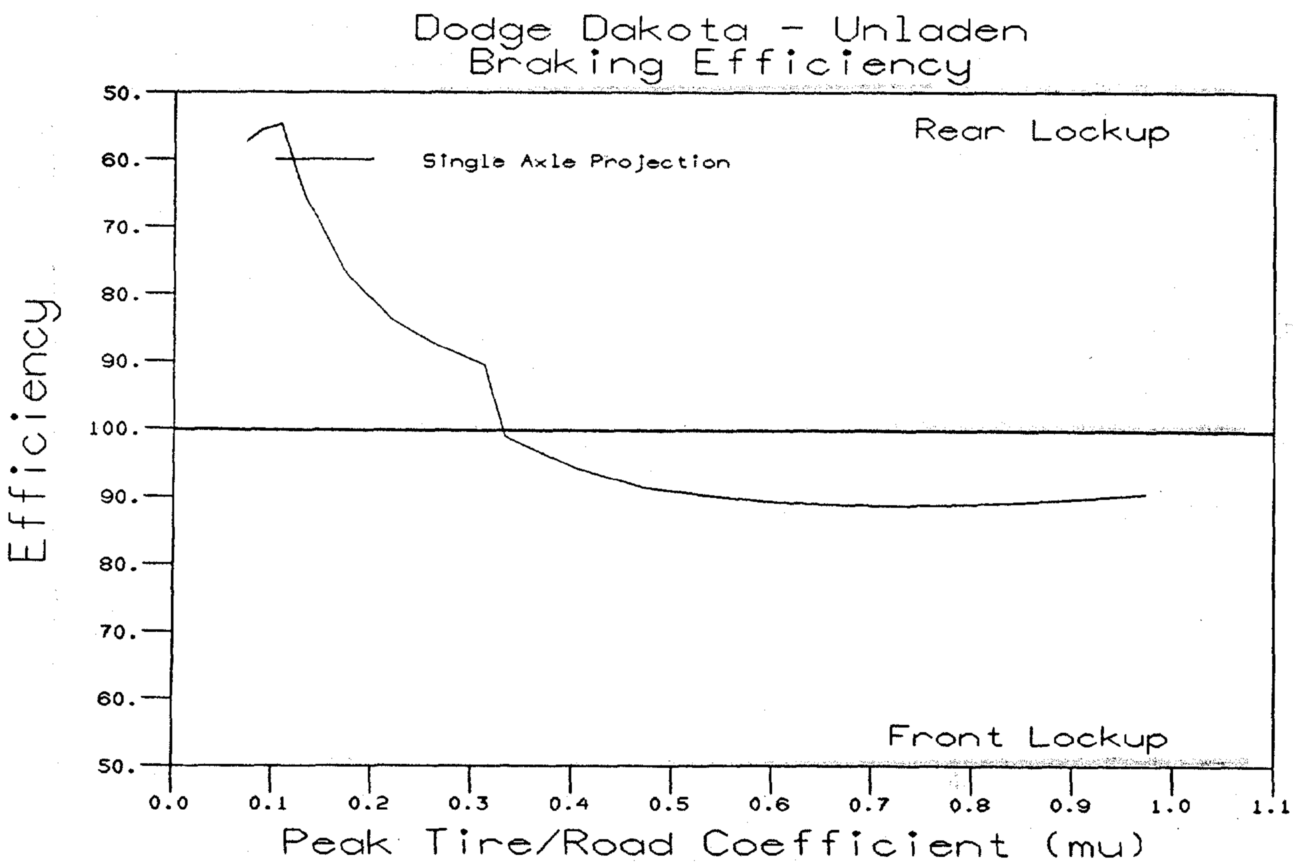
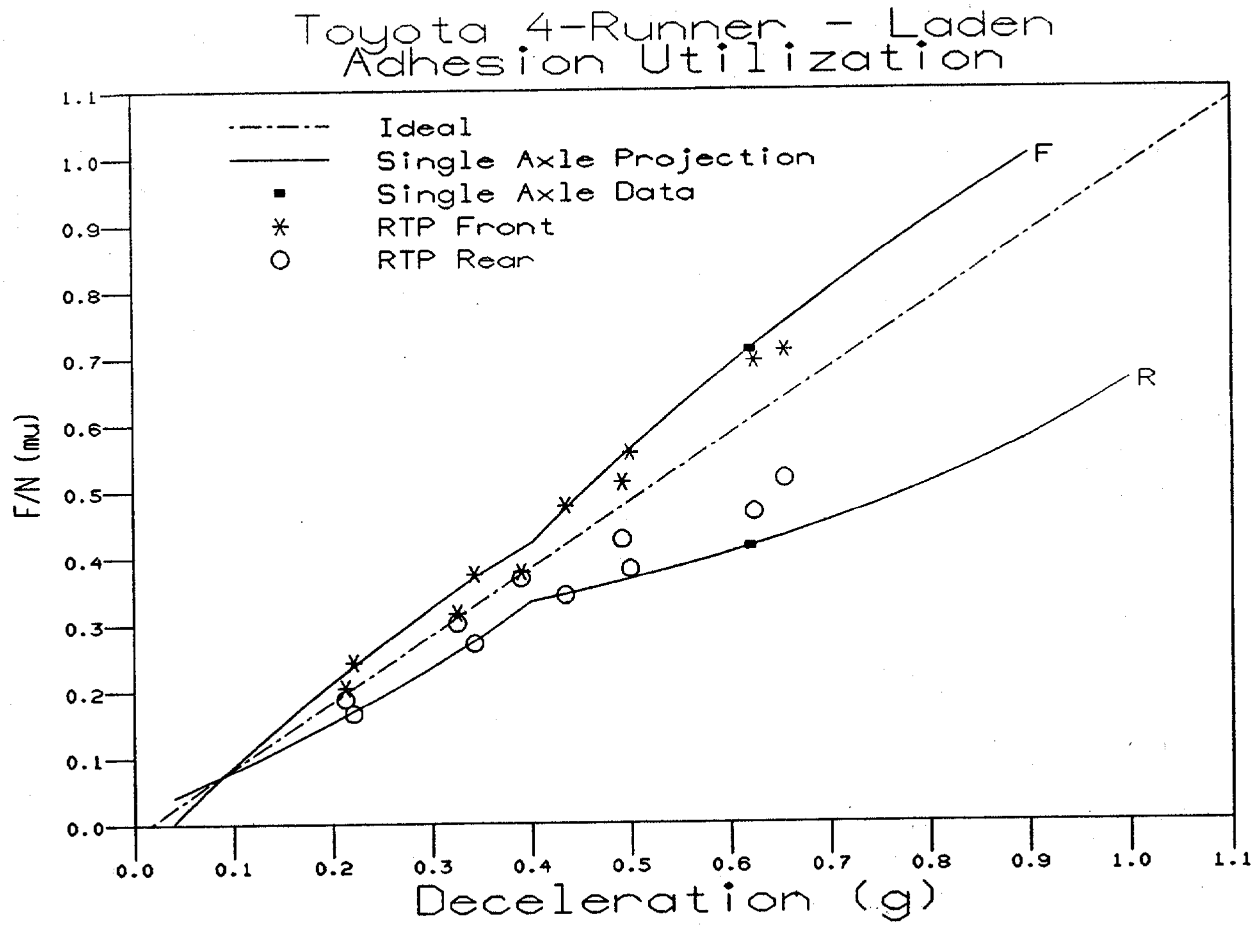

Dodge Dakota - Unladen
Braking Efficiency
Rear Lockup
Single Axle Projection
Front Lockup
Efficiency
Peak Tire/Road Coefficient (mu)

FIGURE 48


Toyota 4-Runner - Laden
Adhesion Utilization
Ideal
Single Axle Projection
Single Axle Data
RTP Front
RTP Rear
F
R
F/N (mu)
Deceleration (g)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1

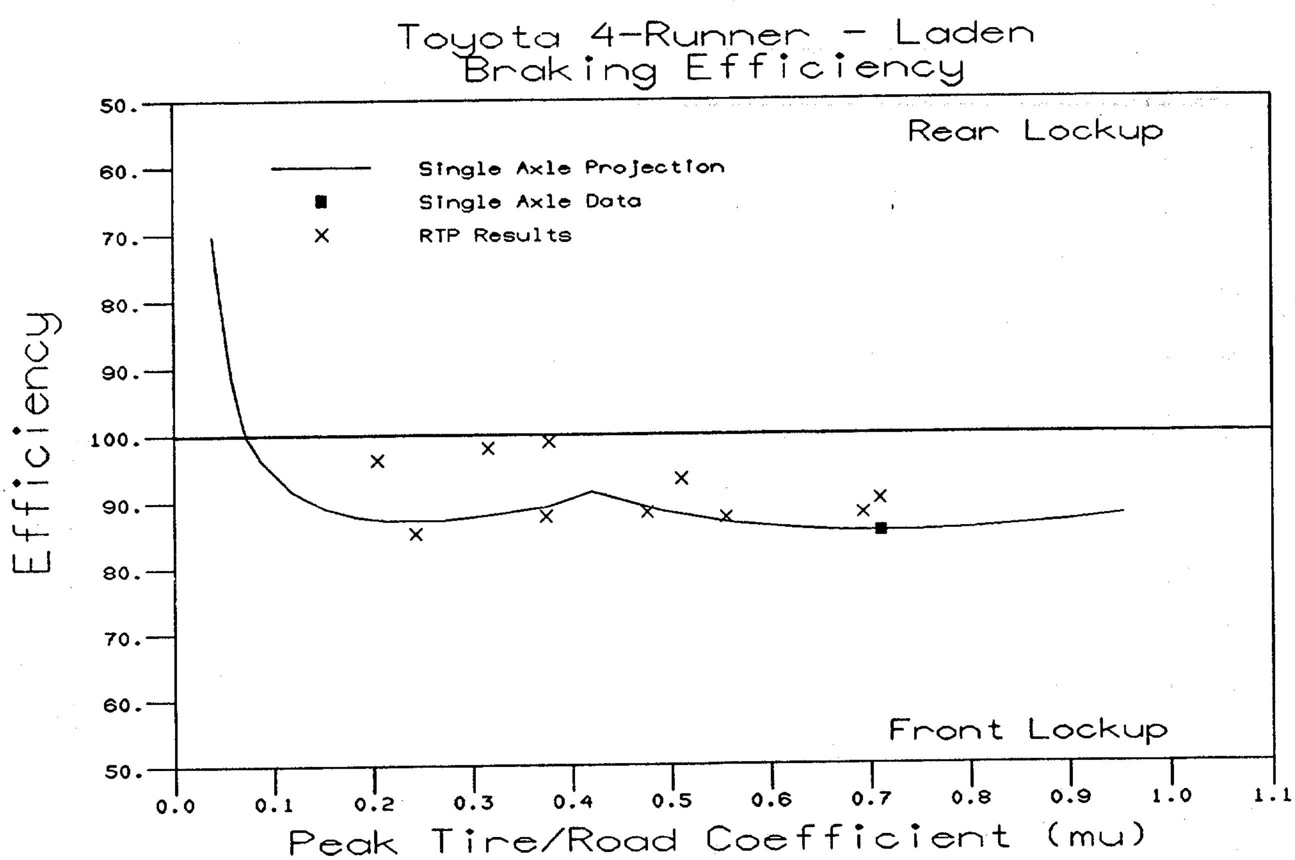
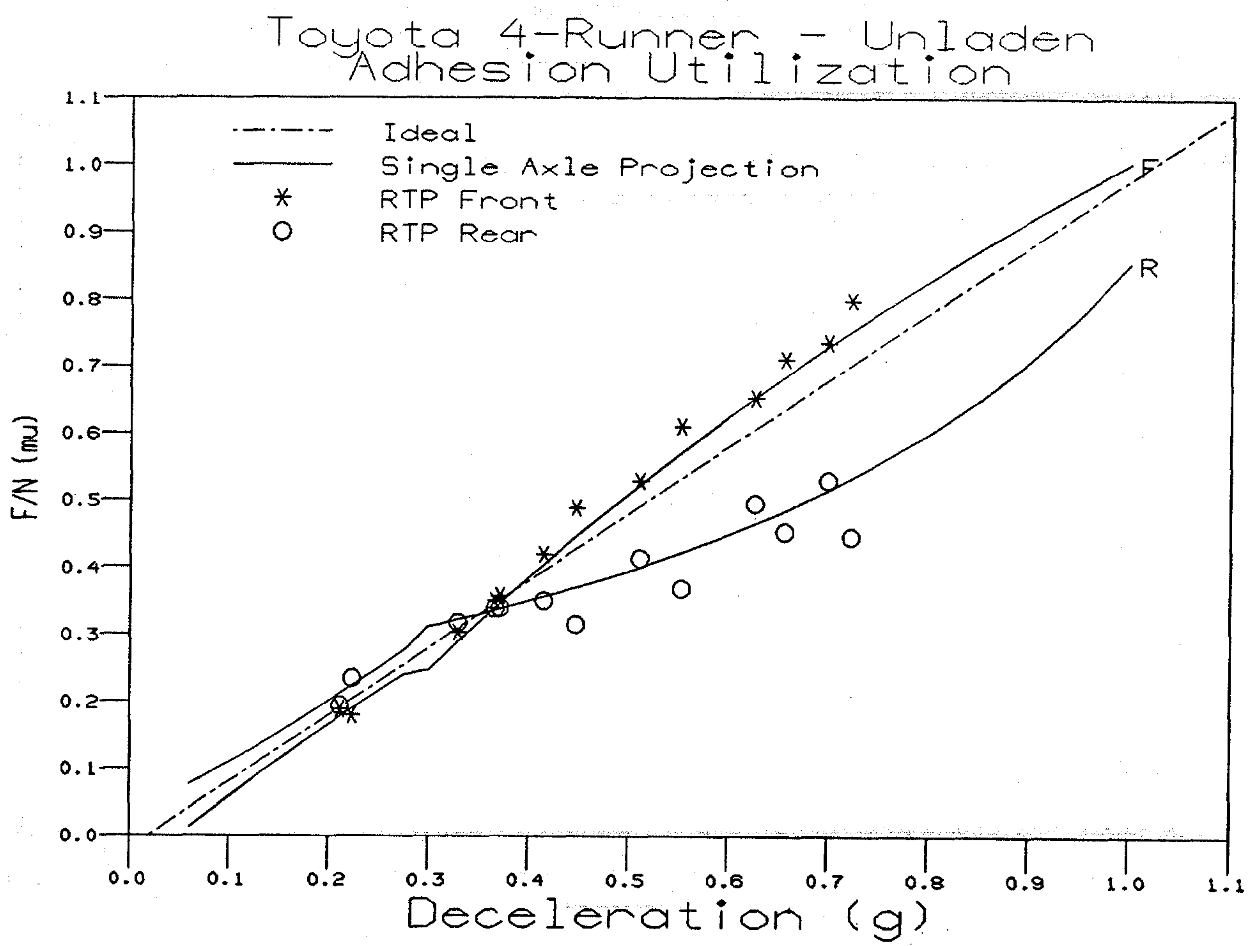

Toyota 4-Runner - Laden
Braking Efficiency
Rear Lockup
Single Axle Projection
Single Axle Data
RTP Results
Front Lockup
Efficiency
Peak Tire/Road Coefficient (mu)
50.
60.
70.
80.
90.
100.
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1

FIGURE 49


Toyota 4-Runner - Unladen
Adhesion Utilization
Ideal
Single Axle Projection
RTP Front
RTP Rear
F
R
F/N (mu)
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
Deceleration (g)

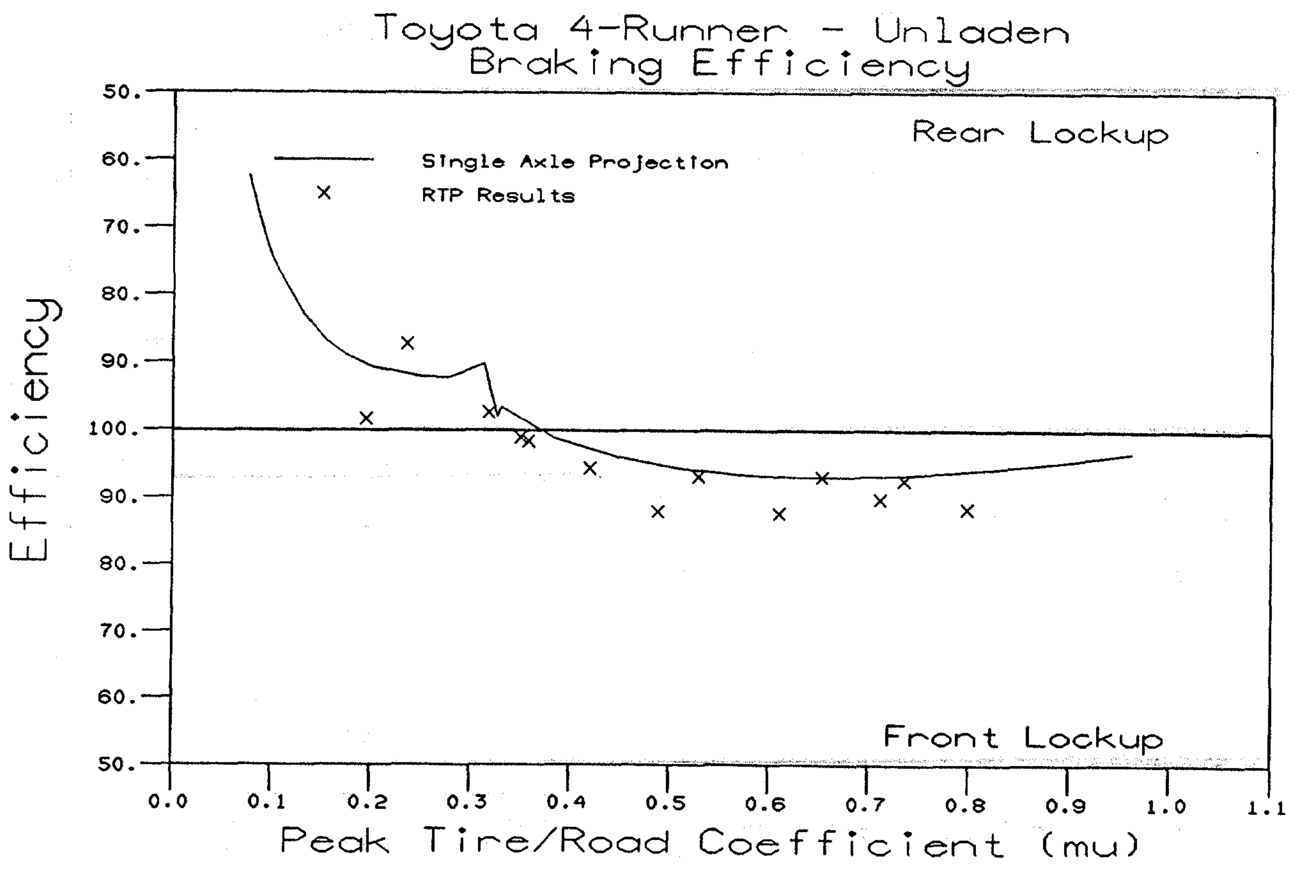
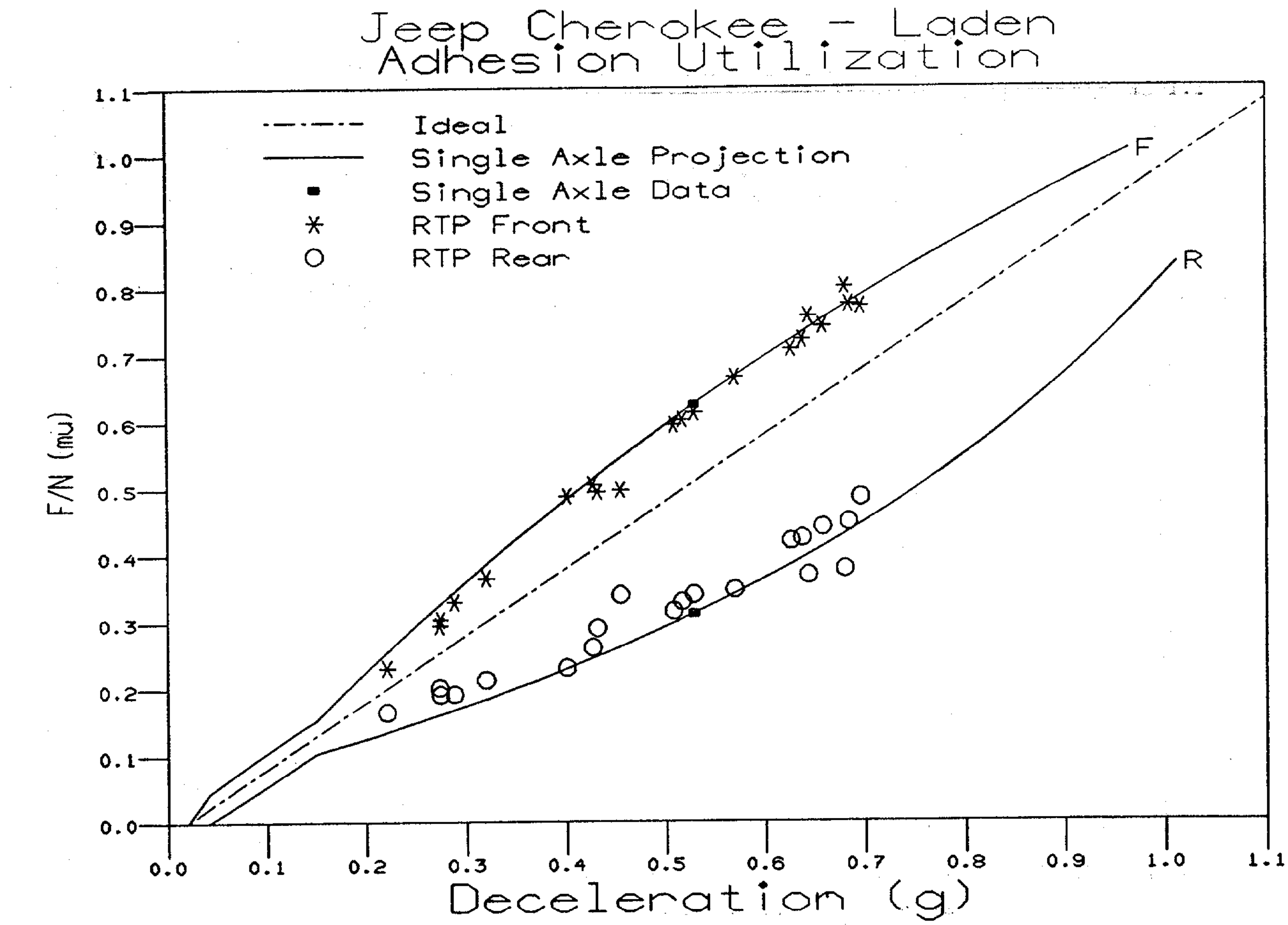
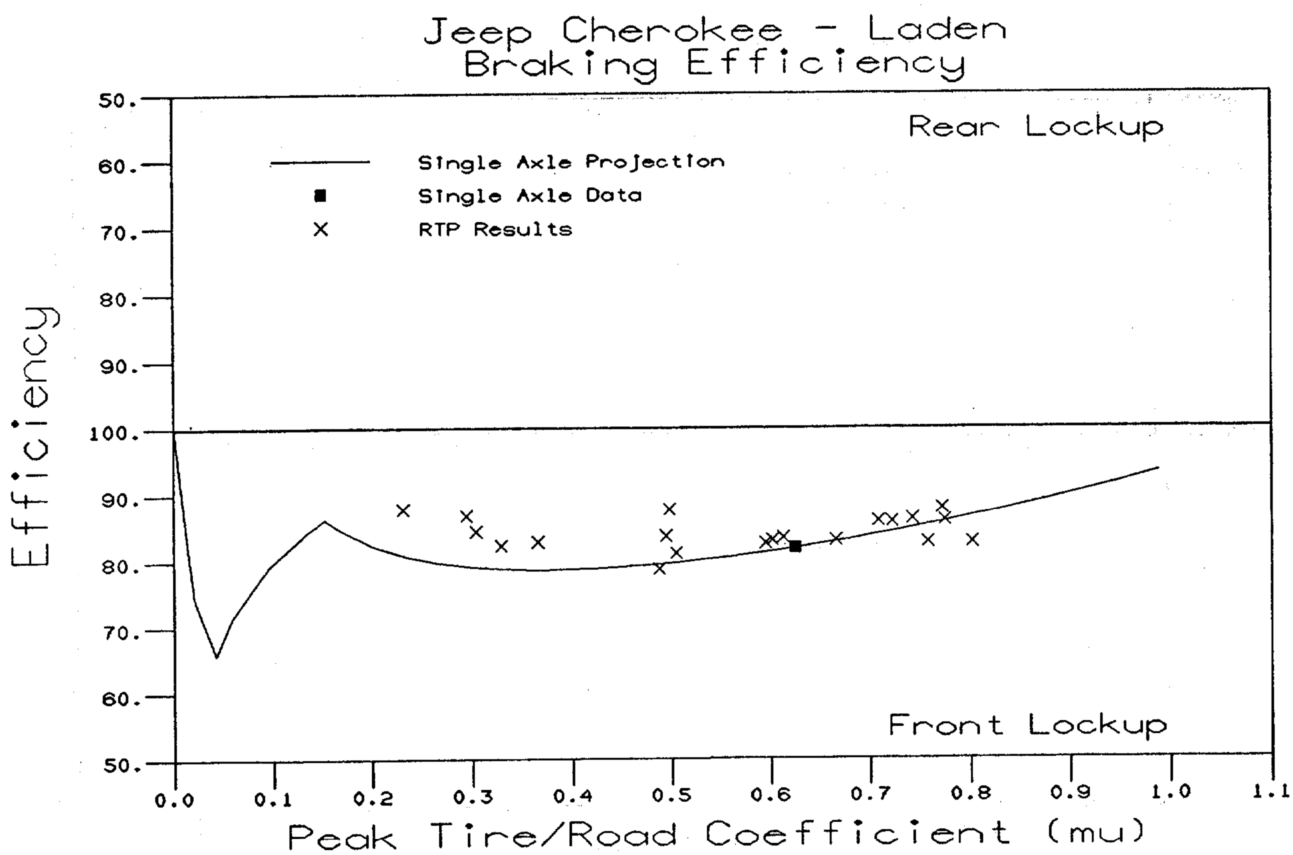

Toyota 4-Runner - Unladen
Braking Efficiency
Rear Lockup
Single Axle Projection
RTP Results
Front Lockup
Efficiency
50.
60.
70.
80.
90.
100.
90.
80.
70.
60.
50.
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
Peak Tire/Road Coefficient (mu)

FIGURE 50



Jeep Cherokee - Laden
Adhesion Utilization
Ideal
Single Axle Projection
Single Axle Data
RTP Front
RTP Rear
F
R
F/N (mu)
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
Deceleration (g)



Jeep Cherokee - Laden
Braking Efficiency
Rear Lockup
Single Axle Projection
Single Axle Data
RTP Results
Front Lockup
Efficiency
50.
60.
70.
80.
90.
100.
90.
80.
70.
60.
50.
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
Peak Tire/Road Coefficient (mu)

FIGURE 51

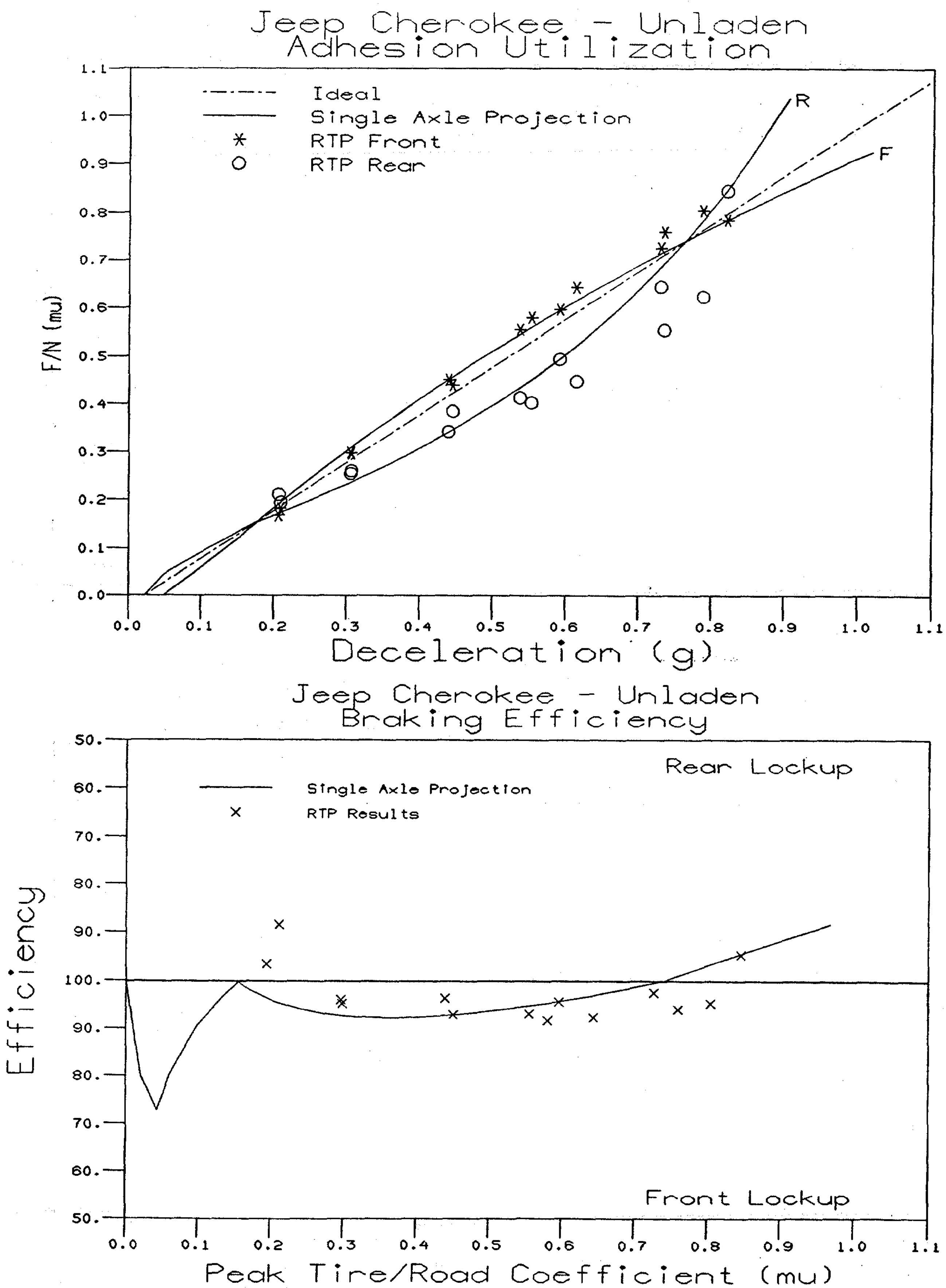

Jeep Cherokee - Unladen
Adhesion Utilization
Ideal
Single Axle Projection
RTP Front
RTP Rear
R
F
F/N (mu)
Deceleration (g)
Jeep Cherokee - Unladen
Braking Efficiency
Rear Lockup
Single Axle Projection
RTP Results
Front Lockup
Efficiency
Peak Tire/Road Coefficient (mu)

FIGURE 52

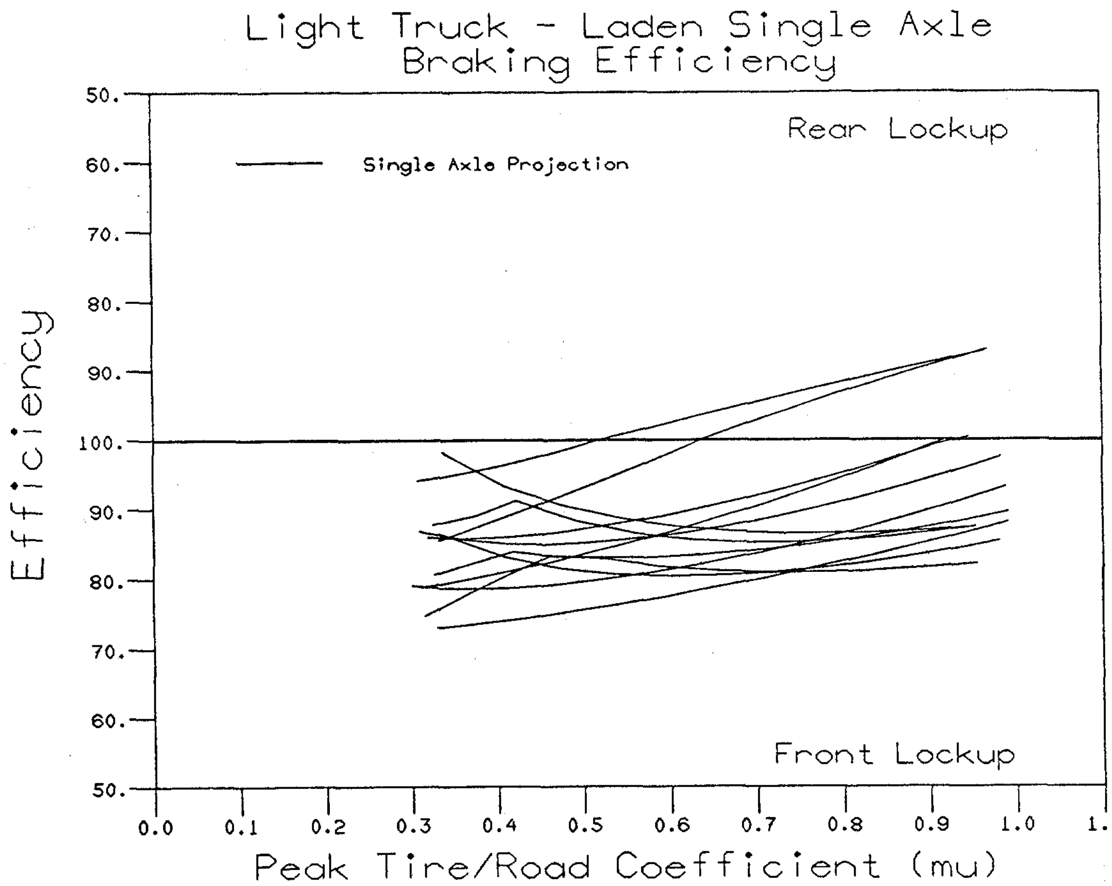


FIGURE 53

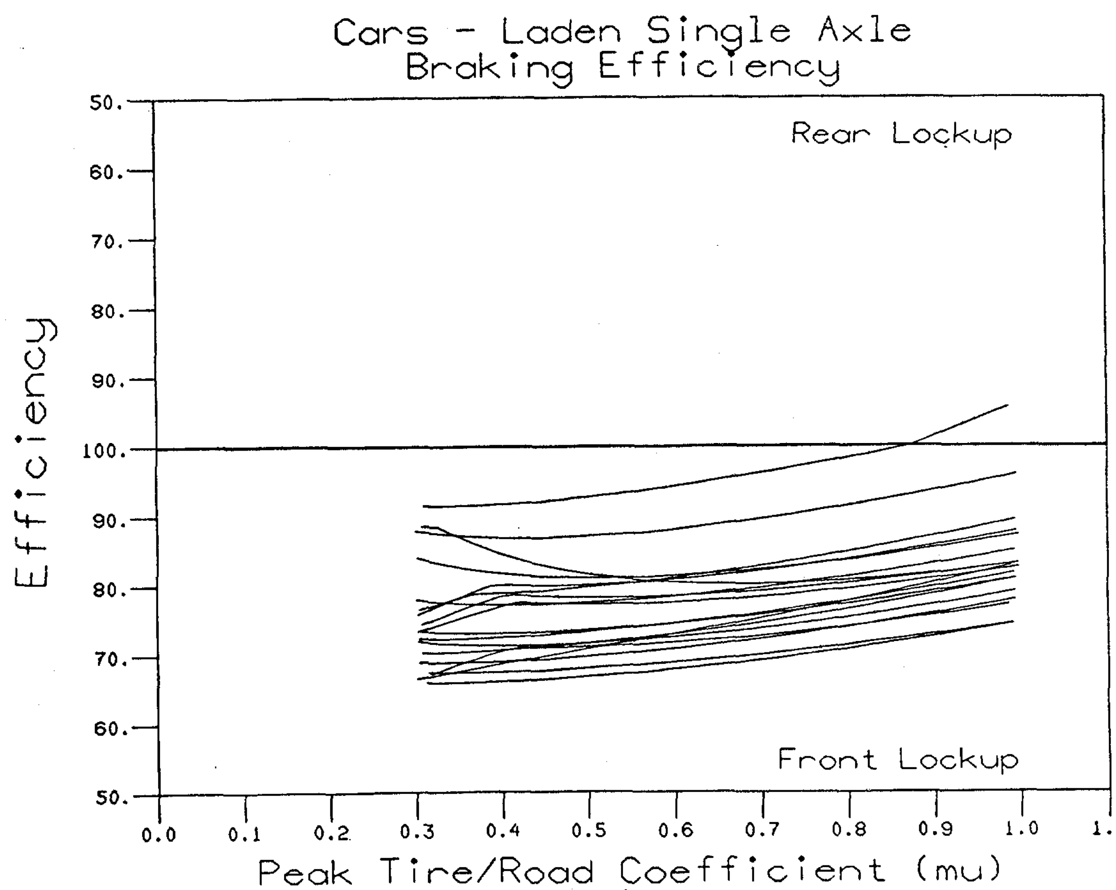
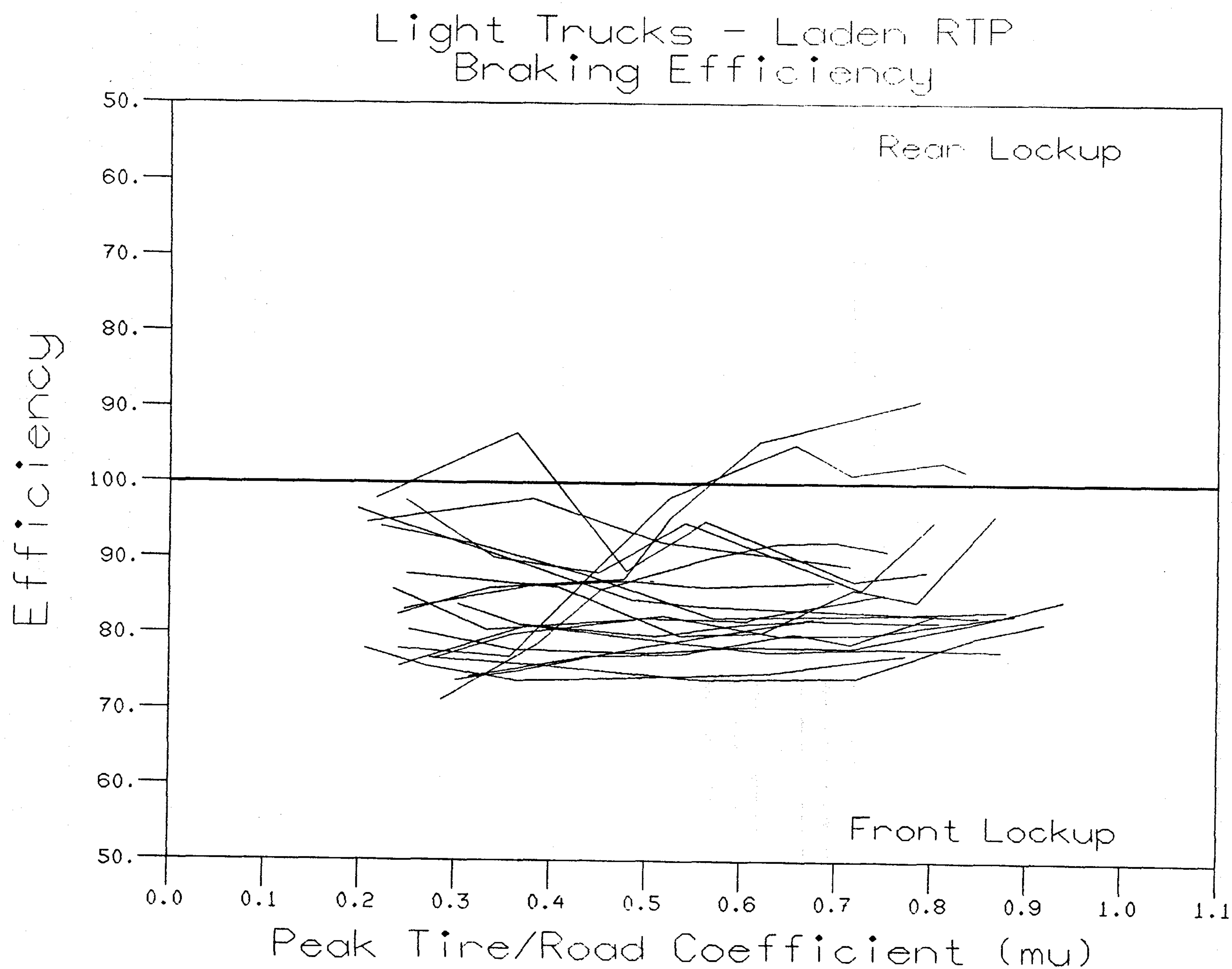


FIGURE 54



Light Trucks - Laden RTP
Braking Efficiency
Rear Lockup
Front Lockup
Efficiency
50.
60.
70.
80.
90.
100.
90.
80.
70.
60.
50.
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
Peak Tire/Road Coefficient (mu)

FIGURE 55

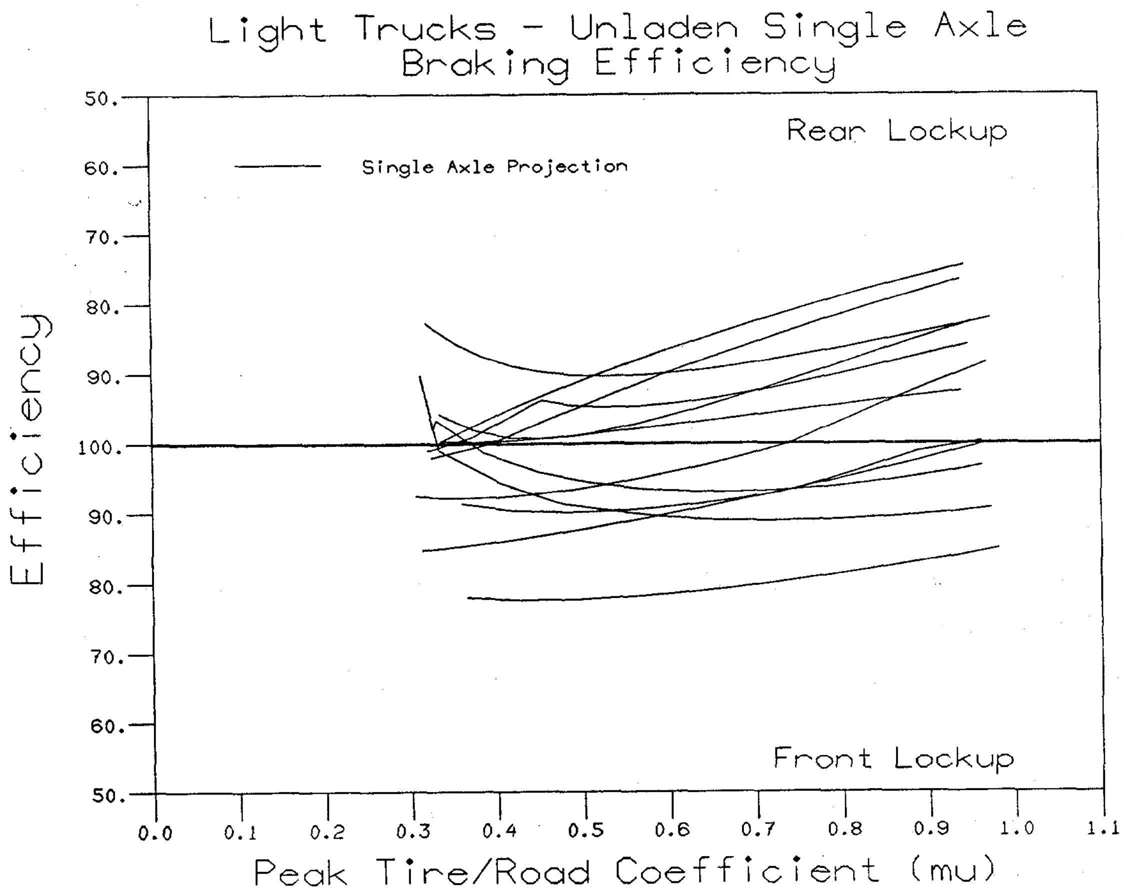


FIGURE 56

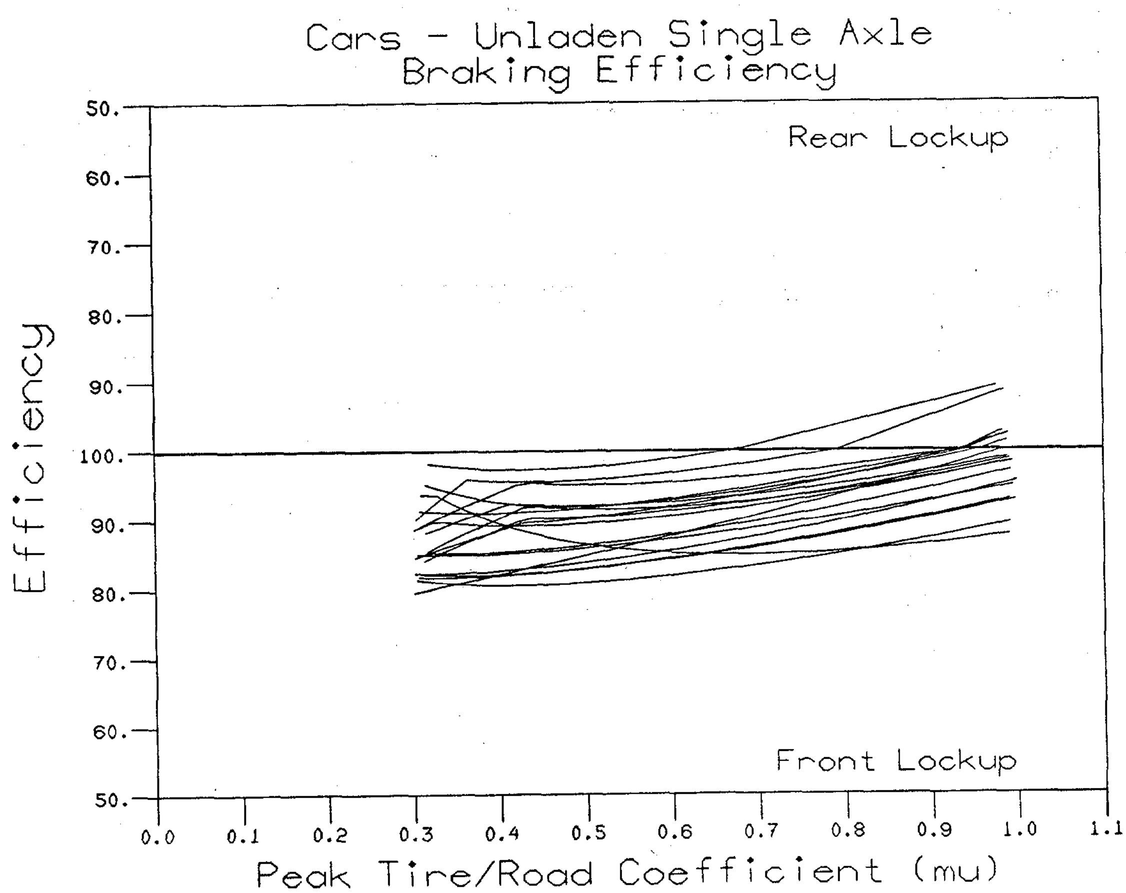


FIGURE 57

Figure 57 and the RTP results are shown in Figure 58. In the laden configuration, the two sets of vehicles have similar braking efficiencies with most of the vehicles being front biased and having efficiencies between 70 percent and 90 percent for mu values above 0.3. For mu values below 0.3, the pushout pressures of the brakes have the greatest effect on the braking efficiency and tends to show a great deal of scatter in this range. For this reason, the braking efficiency is not shown on these plots for mu values below 0.3. With the vehicles in the unladen condition, the light trucks show a wider range in braking efficiency than do the cars. All of the cars showed front brake bias up to higher values of peak tire/road coefficient of friction, while several of the trucks were rear biased at lower values of mu. This difference in performance may be due in part to the greater differences in laden and unladen weights for trucks than cars and, therefore, greater difficulty in compromising the braking efficiency and brake balance for all load conditions.

On nine of the 13 vehicles, the brake balance was measured on two sets of linings. RTP tests were run on these vehicles after one or both of the axle lock sequences and also during the brake distribution tests. A comparison of the results of these two sets of RTP data shows a combination of test variability and an indication of the variability of brake linings. For each of the nine vehicles, composite plots of all of the RTP tests run on that vehicle showing percent rear braking as a function of deceleration are given in Appendix F. For those vehicles equipped with variable proportioning valves, the percent rear braking versus deceleration will change with the load. Generally, these plots show good agreement between the tests with differences in percent rear brake less than 10 percent. Notable exceptions to this are the Nissan, which showed a great deal of run to run scatter during the testing discussed above, and the Ford Ranger which showed brake conditioning during the tests.

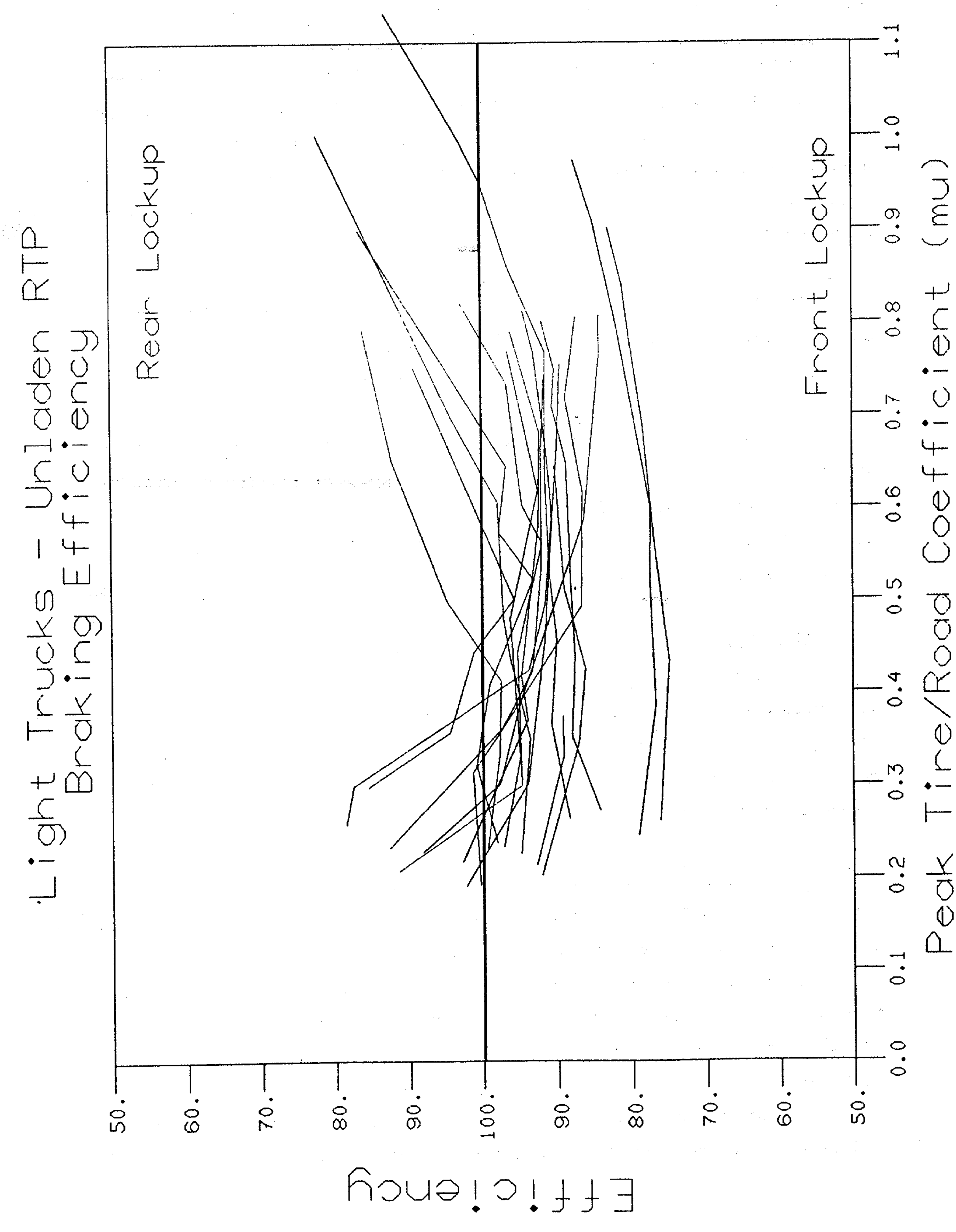

Light Trucks - Unladen RTP
Braking Efficiency
Rear Lockup
Front Lockup
Peak Tire/Road Coefficient (mu)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
Efficiency
50.
60.
70.
80.
90.
100.
90.
80.
70.
60.
50.

FIGURE 58

6.0 SUMMARY AND CONCLUSIONS

Thirteen light trucks were tested to the FMVSS 135 Notice 4 test procedure to investigate the feasibility of using this proposed procedure for these vehicles. The brake balance and center of gravity height of the vehicles was also measured. The vehicles were selected to cover a range of weights up to 8500 lb GVWR with various brake and drive configurations.

In testing the vehicles to the proposed FMVSS 135 test procedure, no problems were found which would suggest the need for a change in the procedure to accommodate this type of vehicle.

Comparing the performance of the light trucks to that of a group of 19 passenger cars tested to the same procedure, the average performance for the two sets of vehicles differed by less than 11 percent on all of the test sections with the light truck performance being better on some sections and the cars better on other sections.

The brake balance of all of the light trucks was measured using a single axle brake distribution procedure and 11 of the vehicles were also measured using a Road Transducer Plate (RTP) facility. For those 11 cases where both methods were used, the agreement between the methods was good for nine of the vehicles with the other two showing unexplained discrepancies.

Brake distrubution tests (as well as axle lock sequence tests run in the FMVSS 135 Notice 4 procedure) indicate that most of the light trucks would lock their front wheels first on all surfaces when fully loaded. The braking efficiency ranged from 70 percent front biased to 88 percent rear biased. In the unladen condition, a number of the vehicles would be rear biased on many surfaces. The braking efficiency ranged from 77 percent front biased to 75 percent rear biased. Brake distribution tests on the group of 19 passenger cars indicated that most of these vehicles would be front biased under all conditions of surface and load with braking efficiencies of 65 percent front biased to 90 percent rear biased.

7.0 ACKNOWLEDGEMENTS

The discussion and views expressed in this report are those of the authors and not necessariloy those of the NHTSA.

The authors wish to thank the following persons at VRTC and TRC for their significant contributions to this report: Dave Hand (TRC) for vehicle preparation and conducting vehicle tests, Doyle McPherson and Dan DeLisle (TRC) for instrumentation support, and Susan Weiser (VRTC) for preparation of the report.

8.0 REFERENCES

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2. Flick, M. and Radlinski, R.W., "Harmonization of Braking Regulations -- Report Number 2, Evaluation of Second Proposed Test Procedure for Passenger Cars," National Highway Traffic Safety Administration, Final Report, DOT HS 806 751, May 1985.

3. Flick, M. and Radlinski, R.W., "Harmonization of Braking Regulations -- Report Number 3, Evaluation of Third Proposed Test Procedure for Passenger Cars," National Highway Traffic Safety Administration, Final Report, DOT HS 806 752, May 1985.

4. Flick, M. and Radlinski, R.W., "Harmonization of Braking Regulations -- Report Number 4, Testing to Address Issues Raised During Development of the NPRM," National Highway Traffic Safety Administration, Final Report, DOT HS 806 820, July 1985.

5. Flick, M. and Radlinski, R.W., "Harmonization of Braking Regulations -- Report Number 5, Testing for Development and Evaluation of the Supplemental Notice of Proposed Rulemaking on Harmonization of Passenger Car Brake Standards," National Highway Traffic Safety Administration, Final Report, DOT HS 807 127, May 1987.

6. Wolanin, W.J. and Baptist, T.A., Road Transducer- Objective Brake Balance Measurement Without Vehicle Instrumentation, SAE 870266 (1987)

7. Garrott, W.R., Chrstos, J.P., and Monk, M.W., "Vehicle Inertial Parameters - Measured Values and Approximations," Draft SAE Paper, 1988.

8. Radlinski, R.W. and Flick, M., "A Vehicle Test Procedure for Determining Adhesion Utilization Properties," SAE Paper #840334.

APPENDIX A

Detailed Test Procedure

S7.1. Burnish.

S7.1.1. General Information.

Any pretest instrumentation checks are conducted as part of the burnish procedure, including any necessary rechecks after instrumentation repair, replacement or adjustment. Instrumentation check test conditions must be in accordance with the burnish test procedure specified in S7.1.2 and S7.1.3.

S7.1.2. Vehicle Conditions.

(a) Vehicle load: GVWR only.

(b) Transmission position: In gear.

S7.1.3 Test Conditions and Procedures.

(a) IBT: $\leq$ 100°C (212°F).

(b) Test speed: 80 km/h (49.7 mph).

(c) Pedal force: $\leq$ 500 N (112.4 lb).

(d) Decel rate: 3 m/s^2 (9.9 fps^2).

(e) Wheel lockup: No lockup of any wheel allowed at speeds greater than 15 km/h (9.3 mph).

(f) Number of runs: 200 stops.

(g) Interval between runs: The interval from the start of one service brake application to the start of the next is either the time necessary to reduce the IBT to 100°C (212°F) or less, or the distance of 2 km (1.24 miles), whichever occurs first.

(h) Accelerate to 80 km/h (49.7 mph) after each stop and maintain that speed until making the next stop.

(i) After burnishing, adjust the brakes as specified in S6.3.4.

S7.2. Low Coefficient Effectiveness.

S7.2.1. General Information.

This test is for vehicles with or without antilock brake systems. This test and that specified in S7.3 for wheel lockup sequence are meant to be a check of the adhesion utilization characteristics of the vehicle.

S7.2.2. Vehicle Conditions.

(a) Vehicle load: GVWR and LLVW.

(b) Transmission position: In neutral.

S7.2.3. Test Conditions and Procedures.

(a) IBT: $\geq$ 50°C (122°F) $\leq$ 100°C (212°F) $\leq$.

(b) Test speed: 50 km/h (31.1 mph) for each stop.

(c) Pedal force: $\leq$ 500 N (112.4 lbs).

(d) Wheel lockup: No lockup of any wheel allowed at speeds greater than 15 km/h (9.3 mph).

(e) Number of runs: 6 stops.

(f) Test surface: Skid number 20 (wet).

(g) For each stop, bring the vehicle to test speed and then stop the vehicle in the shortest possible distance under the specified conditions.

S7.3. Wheel Lockup Sequence.

S7.3.1. General Information.

(a) The purpose of this test is to ensure that lockup of both front wheels occurs simultaneously or at a lower deceleration rate than the lockup of both rear wheels when tested on road surfaces with skid numbers of 20 and 50.

(b) A simultaneous lockup of the front and rear wheels refers to the condition when the time interval between the lockup of the last (second) wheel on the rear axle and the last (second) wheel on the front axle is $\leq$ 0.1 seconds for vehicle speeds $\geq$ 15 km/h (9.3 mph).

S7.3.2. Vehicle Conditions.

(a) Vehicle load: GVWR and LLVW.

(b) Transmission position: In neutral.

S7.3.3 Test Conditions and Procedures.

(a) IBT: $\geq$ 50°C (122°F) $\leq$ 100°C (212°F) $\leq$.

(b) Test speed: 65 km/h (40.4 mph).

(c) Initial pedal force: 45 N (10.1 lb)

(d) Pedal force:

(1) Pedal force is applied and controlled by a mechanical brake pedal actuator.

(2) Pedal force must reach its full application level within 1/2 second and be held within $\pm$ 4.5 N (1.0 lb).

(3) Pedal force is increased in predetermined increments until either a simultaneous lockup occurs, or both wheels on one axle and one or no wheels on the second axle lock.

(e) Wheel lockup: Only wheel lockups above a vehicle speed of 15 km/h (9.3 mph) are considered.

(f) Test surface: This test is conducted first on a surface with a skid number of 20 (wet) and then on a surface with a skid number of 50 (wet).

(g) Data to be recorded. The following six channels of analog information must be automatically recorded in phase continuously throughout each test run in such a way that values of the six variables can be cross referenced in real time:

(1) Vehicle speed.

(2) Brake pedal force.

(3) Angular velocity at each wheel.

(h) If a failure occurs, the operating conditions at failure are specified in terms of vehicle speed at rear lockup and the time intervals between wheels which lock.

(i) The test is conducted according to the following steps:

(1) Initial pedal force for the first stop is:

(i) 45 N (10 lb) on the skid number 20 surface.

(ii) 90 N (20 lb) on the skid number 50 surface.

(2) Make one constant pedal force stop from 65 km/h (40.4 mph).

(3) Increase the pedal force by 45 N (10 lb) and repeat step 2.

(4) Repeat steps 2 and 3 as long as the result achieved for each stop is one or no wheels locking on each axle.

(5) As steps 2 and 3 are repeated, if both wheels on the front axle and one or no wheels on the rear axle lock, do not repeat steps 2 and 3 beyond this point (pedal force) of front axle lockup. Make two more stops at the same pedal force level. At this point the lockup sequence has been determined and the test is complete.

(6) As steps 2 and 3 are repeated, if both wheels on the rear axle and one or no wheels on the front axle lock, make two more stops at the same pedal force level and:

(i) If at least one of these two additional stops yields the same result as the first stop, then the lockup sequence has been determined and the test is complete.

(ii) If the results of both of these additional stops is different from that obtained for the first stop, increase the pedal force by 10 N (2.2 lb) and make three more stops. Continue this process until at least two of the three stops result in one of the following:

(A) Both wheels on the rear axle and one or no wheels on the front axle lock, or

(B) All four wheels lock.

(iii) When either of the conditions described in Paragraphs (i)(6)(ii)(A) or (i)(6)(ii)(B) of this section occurs, the lockup sequence has been determined and the test is complete.

(7) As steps 2 and 3 are repeated, if all four wheels lock, reduce the pedal force by 20 N (4.5 lb) and make one stop.

(i) If both wheels on the front axle and one or no wheels on the rear axle lock, or both wheels on the rear axle and one or no wheels on the front axle lock, make two additional stops. If at least one of the two additional stops does not result in the same lockup sequence as the first stop, increase the pedal force by 10 N (2.2 lb) and make three stops. At this point the lockup sequence has been determined and the test is complete.

(ii) If one or no wheels on each axle lock, increase the pedal force level in increments of 10 N (2.2

lb) and make one stop at each new pedal force level until either of the following occurs:

(A) Both wheels on the front axle and one or no wheels on the rear axle lock, or

(B) Both wheels on the rear axle and one or no wheels on the front axle lock.

(iii) When either of the conditions described in Paragraphs (i)(7)(ii)(A) or (i)(7)(ii)(B) of this section occurs, make two additional stops at that pedal force level. If at least one of the two additional stops results in the same lockup sequence as the first stop at that pedal force level, the lockup sequence has been determined and the test is complete.

S7.4. Cold Effectiveness.

S7.4.1. Vehicle Conditions.

(a) Vehicle load: GVWR and LLVW.

(b) Transmission position: In neutral.

S7.4.2. Test Conditions and Procedures.

(a) IBT: $\geq$ 50°C (122°F) $\leq$ 100°C (212°F) $\leq$.

(b) Test speed: 100 km/h (62.1 mph).

(c) Pedal force: $\geq$ 65 N (14.6 lb) $\leq$ 500 N (112.4 lb).

(d) Wheel lockup: No lockup of any wheel allowed at speeds greater than 15 km/h (9.3 mph).

(e) Number of runs: 6 stops.

(f) Test surface: Skid number 81 (dry).

(g) For each stop, bring the vehicle to test speed and then stop the vehicle in the shortest possible distance under the specified conditions.

S7.5. High Speed Effectiveness.

S7.5.1. Vehicle Conditions.

(a) Vehicle load: GVWR and LLVW.

(b) Transmission position: In gear.

S7.5.2. Test Conditions and Procedures.

(a) IBT: $\geq$ 50°C (122°F) $\leq$ 100°C (212°F) $\leq$.

(b) Test speed: 80% of vehicle masimum speed.

(c) Pedal force: $\geq$ 65 N (14.6 lb) $\leq$ 500 N (112.4 lb).

(d) Wheel lockup: No lockup of any wheel allowed at speeds greater than 15 km/h (9.3 mph).

(e) Number of runs: 6 stops.

(f) Test surface: Skid number 81 (dry).

S7.6. Partial Failure - Stops With Engine Off.

S7.6.1. General Information.

This test is for vehicles equipped with one or more brake power units or brake power assist units.

S7.6.2. Vehicle Conditions.

(a) Vehicle load: GVWR only.

(b) Transmission position: In neutral.

S7.6.3. Test Conditions and Procedures.

(a) IBT: $\geq$ 50°C (122°F) $\leq$ 100°C (212°F) $\leq$.

(b) Test speed: 100 km/h (62.1 mph).

(c) Pedal force: $\geq$ 65 N (14.6 lb) $\leq$ 500 N (112.4 lb).

(d) Wheel lockup: No lockup of any wheel allowed at speeds greater than 15 km/h (9.3 mph).

(e) Number of runs: 6 stops.

(f) Test surface: Skid number 81 (dry).

(g) All system reservoirs (brake power and/or power assist units are fully charged and the vehicle's engine off (not running) at the beginning of each stop.

S7.7. Antilock Failure.

S7.7.1. Vehicle Conditions.

(a) Vehicle load: GVWR and LLVW.

(b) Transmission position: In neutral.

S7.7.2. Test Conditions and Procedures.

(a) IBT: $\geq$ 50°C (122°F) $\leq$ 100°C (212°F) $\leq$.

(b) Test speed: 100 km/h (62.1 mph).

(c) Pedal force: $\geq$ 65 N (14.6 lb) $\leq$ 500 N (112.4 lb).

(d) Wheel lockup: No lockup of any wheel allowed at speeds greater than 15 km/h (9.3 mph).

(e) Number of runs: 6 stops.

(f) Test surface: Skid number 81 (dry).

(g) Functional failure:

(1) Disconnect the functional power source, or otherwise render the antilock system inoperative.

(2) Determine whether the brake system indicator is activated when any functional failure of the antilock system is created.

(3) Restore the system to normal at the completion of this test.

(h) Structural failure: If an antilock system structural failure would result in the same type of structural failure as a hydraulic circuit failure (S7.9), then the test for antilock structural failure is not conducted here. Otherwise, the test for antilock structural failure is conducted.

(i) If more than one antilock brake subsystem is provided, then repeat test for each subsystem.

S7.8. Variable Proportioning Valve Failure.

S7.8.1. Vehicle Conditions.

(a) Vehicle load: LLVW and GVWR.

(b) Transmission position: In neutral.

S7.8.2. Test Conditions and Procedures.

(a) IBT: $\geq$ 50°C (122°F) $\leq$ 100°C (212°F) $\leq$.

(b) Test speed: 100 km/h (62.1 mph).

(c) Pedal force: $\geq$ 65 N (14.6 lb) $\leq$ 500 N (112.4 lb).

(d) Wheel lockup: No lockup of any wheel allowed at speeds greater than 15 km/h (9.3 mph).

(e) Number of runs: 6 stops.

(f) Test surface: Skid number 81 (dry).

(g) Functional failure:

(1) Disconnect the functional power source or disconnect the variable proportioning brake system.

(2) Determine whether the brake system indicator is activated when any functional failure of the variable proportioning system is created.

(3) Restore the system to normal at the completion of this test.

(h) Structural failure: If a variable prportioning valve system structural failure would result in the same type of structural failure as a hydraulic circuit failure (S7.9), then the test for a variable proportioning valve structure failure is not conducted here. Otherwise, the test for a variable proportioning valve structural failure is conducted.

(i) If more than one variable proportioning brake subsystem is provided, then repeat the test for each subsystem.

S7.9. Partial Failure - Hydraulic Circuit Failure.

S7.9.1. General Information.

This test is for vehicles manufactured with and without a split service brake system.

S7.9.2. Vehicle Conditions.

(a) Vehicle load: LLVW and GVWR.

(b) Transmission position: In neutral.

S7.9.3. Test Conditions and Procedures.

(a) IBT: $\geq$ 50°C (122°F) $\leq$ 100°C (212°F) $\leq$.

(b) Test speed: 100 km/h (62.1 mph).

(c) Pedal force: $\geq$ 65 N (14.6 lb) $\leq$ 500 N (112.4 lb).

(d) Wheel lockup: No lockup of any wheel allowed at speeds greater than 15 km/h (9.3 mph).

(e) Alter the service brake system to produce any one rupture or leakage type of failure, other than a structural failure of a housing that is common to two or more subsystems.

(f) Determine the control force, pressure level, or fluid level (as appropriate for the indicator being tested) necessary to activate the brake warning indicator.

(g) Number of runs: After the brake warning indicator has been activated, make the following stops depending on the type of brake system:

(1) 4 stops for a split service brake system.

(2) 10 consecutive stops for a non-split service brake system.

(h) Each stop is made by a continuous application of the service brake control.

(i) Restore the service brake system to normal at the completion of this test.

(j) Repeat the entire sequence for each of the other systems.

S7.10. Partial Failure - Power Brake Unit or Brake Power Assist Unit Inoperative (System Depleted).

S7.10.1 General Information.

This test is for vehicles equipped with one or more brake power units or brake power assist units.

S7.10.2. Vehicle Conditions.

(a) Vehicle load: GVWR only.

(b) Transmission position: In neutral.

S7.10.3. Test Conditions and Procedures.

(a) IBT: $\geq$ 50°C (122°F) $\leq$ 100°C (212°F) $\leq$.

(b) Test speed: 100 km/h (62.1 mph).

(c) Pedal force: $\geq$ 65 N (14.6 lb) $\leq$ 500 N (112.4 lb).

(d) Wheel lockup: No lockup of any wheel allowed at speeds greater than 15 km/h (9.3 mph).

(e) Number of runs: 6 stops.

(f) Test surface: Skid number 81 (dry).

(g) Disconnect the primary source of power for one brake power assist unit or brake power unit, or one of the brake power unit or brake power assist unit subsystems if two or more subsystems are provided.

(h) If the brake power unit or power assist unit operates in conjunction with a backup system and the backup system is automatically activated in the event of a primary power service failure, the backup system is operative during this test.

(i) Exhaust any residual brake power reserve capability of the disconnected system.

(j) Make each of the 6 stops by a continuous application of the service brake control.

(k) Restore the system to normal at completion of this test.

(l) For vehicles equipped with more than one brake power unit or brake power assist unit, conduct tests for each in turn.

S7.11. Parking Brake - Static Test.

S7.11.1. Vehicle Conditions.

(a) Vehicle load: GVWR only.

(b) Transmission position: In neutral.

(c) Parking brake burnish:

(1) For vehicles with parking brake systems not utilizing the service friction elements, the friction elements of such a system are burnished prior to the parking brake test according to the published recommendations furnished to the purchaser by the manufacturer.

(2) If no recommendations are furnished, the vehicle's parking brake system is tested in an unburnished condition.

<u>S7.11.2. Test Conditions and Procedures.</u>

(a) IBT: $\leq$ 100°C (212°F).

(b) Parking brake control force: Hand control $\leq$ 400 N (89.9 lb); foot control $\leq$ 500 N (112.4 lb).

(c) Hand force measurement locations: The force required for actuation of a hand-operated brake system is measured at the center of the actuation lever, as illustrated in Figure 2.

(d) Parking brake applications: 1 apply and 2 reapply if necessary.

(e) Test surface gradient: 20% grade.

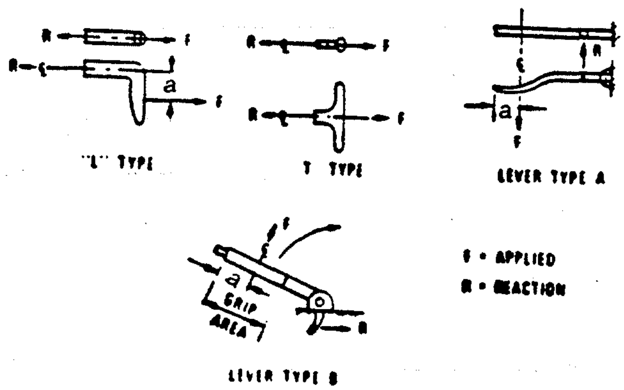
(f) Drive the vehicle onto the grade with the longitudinal axis of the vehicle in the direction of the slope of the grade.

(g) Stop the vehicle and hold it stationary by applying the service brake control and place the transmission in neutral.

(h) With the service brake applied sufficiently to just keep the vehicle from rolling, apply the parking brake as specified in S7.11.2(i) or S7.11.2(j).

Location for Measuring Brake Application Force

(Hand Brake)



Dimension a = 40 mm (1.57 in)

FIGURE 2

(i) The parking brake system is actuated by a single application not exceeding the limits specified in S7.11.2(b).

(j) In the case of a parking brake system that does not allow application of the specified force in a single application, a series of applications may be made to achieve the specified force.

(k) Following the application of the parking brakes, release all force on the service brake control and, if the vehicle remains stationary, start the measurement of time.

(l) If the vehicle does not remain stationary, reapplication of a force to the parking brake control at the level specified in S7.11.2(b) as appropriate for the vehicle being tested (without release of the ratcheting or other holding mechanism of the parking brake) is used up to two times to attain a stationary position.

(m) Verify the operation of the parking brake application indicator.

(n) Following observation of the vehicle in a stationary condition for the specified time in one direction, repeat the same test procedure with the vehicle orientation in the opposite direction on the same grade.

S7.12. Parking Brake - Dynamic Test.

S7.12.1. Vehicle Conditions.

(a) Vehicle load: GVWR only.

(b) Transmission position: In neutral.

(c) Parking brake burnish: No additional burnishing is allowed beyond that specified in S7.11.1(c).

S7.12.2. Test Conditions and Procedures.

(a) IBT: ≤ 100°C (212°F).

(b) Parking brake control force: Hand control ≤ 400 N (89.9 lb); foot control ≤ 500 N (112.4 lb).

(c) Hand force measurement locations: The force required for actuation of a hand-operated brake system is measured at the center of the hand grip area or at a distance of 40 mm (1.57 in) from the end of the actuation lever, as illustrated in Figure 2.

(d) Number of runs: 2 stops.

(e) Test speed: 60 km/h (37.3 mph).

(f) Wheel lockup: no lockup of any wheel allowed at speeds greater than 15 km/h (9.3 mph).

(g) With the vehicle at a test speed of 60 km/h (37.3 mph), apply the parking brake as specified in S7.12.2(h) or S7.12.2(i).

(h) The parking brake system is actuated by a single application not exceeding the limit specified in S7.12.2(b).

(i) In the case of a parking brake system that does not allow application of the specified force in a single application, a series of applications may be made to achieve the specified force.

S7.13. Heating Snubs.

S7.13.1. General Information.

The purpose of the snubs is to heat up the brakes in preparation for the hot performance test which follows immediately.

S7.13.1. Vehicle Conditions.

(a) Vehicle load: GVWR only.

(b) Transmission position: In gear.

S7.13.2. Test Conditions and Procedures.

(a) IBT:

(1) Establish an IBT before the first brake application (snub) of $\geq$ 55°C (131°F) $\leq$ 65°C (149°F).

(2) IBT's before subsequent snubs are those occurring at the distance intervals.

(b) Number of snubs: 15.

(c) Test speeds: The initial speed for each snub is 120 km/h (74.6 mph) or 80% of Vmax, whichever is slower. Each snub is termianted at one-half the initial speed.

(d) Deceleration rate:

(1) Maintain a constant deceleration rate of 3.0 m/s^2 (9.8 fps^2).

(2) Attain the specified deceleration within one second and maintain it for the remainder of the snub.

(e) Pedal force: $\leq$ 500 N (112.4 lb).

(f) Time interval: Maintain an interval of 40 seconds between the start of brake applications (snubs).

(g) Accelerate as rapidly as possible to the initial test speed immediately after each snub.

(h) Immediately after the 15th snub, accelerate to 100 km/h (62.1 mph) and commence the hot performance test.

S7.14. Hot Performance.

S7.14.1. General Information.

The hot performance test is conducted immediately after completion of the 15th heating snub.

S7.14.2. Vehicle Conditions.

(a) Vehicle load: GVWR only.

(b) Transmission position: In neutral.

S7.14.3. Test Conditions and Procedures.

(a) IBT: Temperature achieved at completion of heating snubs.

(b) Test speed: 100 km/h (62.1 mph).

(c) Pedal force: The pedal force is not greater than the average pedal force achieved during the shortest GVWR cold effectiveness stop.

(d) Wheel lockup: no lockup of any wheel allowed at speeds greater than 15 km/h (9.3 mph).

(e) Number of runs: 2 stops.

(f) Immediately after the 15th heating snub, accelerate to 100 km/h (62.1 mph) and commence the 1st stop of the hot performance test.

(g) If the vehicle is incapable of attaining 100 km/h, it is tested at the same speed used for the GVWR cold effectiveness test.

(h) Immediately after completion of the first hot performance stop, accelerate as rapidly as possible to the specified test speed and conduct the second hot performance stop.

(i) Immediately after completion of second hot performance stop, drive 1.5 km (0.98 mi) at 50 km/h (31.1 mph) before the first cooling stop.

S7.15. Braking Cooling Stops.

S7.15.1. General Information.

The cooling stops are conducted immediately after completion of the hot performance test.

S7.15.2. Vehicle Conditions.

(a) Vehicle load: GVWR only.

(b) Transmission position: In gear.

S7.15.3. Test Conditions and Procedures.

(a) IBT: Temperature achieved at completion of hot performance.

(b) Test speed: 50 km/h (31.1 mph).

(c) Pedal force: $\leq$ 500 N (112.4 lb).

(d) Deceleration rate: maintain constant deceleration rate of 3.0 m/s^2 (9.8 fps^2).

(e) Wheel lockup: No lockup of any wheel allowed at speeds greater than 15 km/h (9.3 mph).

(f) Number of runs: 4 stops.

(g) Immediately after the hot performance stops, drive 1.5 km (0.93 mi) at 50 km/h (31.1 mph) before the first cooling stop.

(h) For the first through the third cooling stops:

(1) After each stop, immediately accelerate at the maximum rate to 50 km/h (31.1 mph).

(2) Maintain that speed until beginning the next stop at a distance of 1.5 km (0.93 mi) from the beginning of the previous stop.

(i) For the fourth cooling stop:

(1) Immediately after the fourth stop, accelerate at the maximum rate to 100 km/h (62.1 mph).

(2) Maintain that speed until beginning the recovery performance stops at a distance of 1.5 km (0.93 mi) after the beginning fo the fourth cooling stop.

S7.15. Recovery Performance.

S7.16.1. General Information.

The recovery performance test is conducted immediately after completion of the brake cooling stops.

S7.16.2. Vehicle Conditions.

(a) Vehicle load: GVWR only.

(b) Transmission position: In neutral.

S7.16.3. Test Conditions and Procedures.

(a) IBT: Temperature achieved at completion of cooling stops.

(b) Test speed: 100 km/h (62.1 mph).

(c) Pedal force: Pedal force is not greater than the average pedal force of the shortest GVWR cold effectiveness.

(d) Wheel lockup: No lockup of any wheel allowed at speeds greater than 15 km/h (9.3 mph).

(e) Number of runs: 2 stops.

(f) Immediately after the fourth cooling stop, accelerate at the maximum rate to 100 km/h (62.1 mph).

(g) Maintain that speed until beginning the first recovery performance stop at a distance of 1.5 km (0.93 mi) after the beginning of the fourth cooling stop.

(h) If the vehicle is incapable of attaining 100 km/h, it is tested at the same speed used for the GVWR cold effectiveness test.

(i) Immediately after completion of the first recovery performance stop, accelerate as rapidly as possible to the specified test speed and conduct the second recovery performance stop.

S7.17. Final Inspection.

Inspect:

(a) The service brake system for detachment or fracture of any components, such as brake springs and brake shoes or disc pad facings.

(b) The friction surface of the brake, the master cylinder or brake power unit reservoir cover, and seal and filler openings, for leakage of brake fluid or lubricant.

(c) The master cylinder or brake power unit reservoir for compliance with the volume and labeling requirements of S5.4.2 and S5.4.3. In determining the fully applied worn condition, assume that the lining is worn to (1) rivet or bolt heads on riveted or bolted linings or (2) within 0.8 mm

(1.32 in) of shoe or pad mounting surface on bonded linings or (3) the limit recommended by the manufacturer, whichever is larger relative to the total possible shoe or pad movement. Drums or rotors are assumed to be at nominal design drum diameter or rotor thickness. Linings are assumed adjusted for normal operating clearance in the released position.

(d) The brake system indicators, for compliance with operation in various key positions, lens color, labeling, and location, in accordance with S5.5.

APPENDIX B

Vehicle Information and Summary Data Sheets

Test Vehicle Information/Specifications

Vehicle Type: Van | Wheelbase: 2845 mm

Manufacturer: Dodge | Model: Caravan

VIN: 2B4FK41K5JR521196 | Production Date: 9/87

GVWR: 2200 kg GAWR - Frt: 1100 kg Rear: 1111 kg

Engine-Type: Gas | No. Cyl: 4 | Disp: 2.5 l

Transmission-Type: Automatic | Fwd Spds: 3 | Drive Axle: Rear

Tires-Mfgr: Goodyear | Style: Radial

Size: P195/75 R14 | Test Press - Frt: 2.4 bar Rear: 2.4 bar

Grade	LF	RF	LR	RR
Treadwear:	280	280	280	280
Traction:	A	A	A	A
Temperature:	B	B	B	B
Serial Number:	NA	NA	NA	NA
Estimated Mileage:	1500	1500	1500	1500

Brake System - Booster-Type: Vacuum

Parking Brake-Type: Rear Shoes | Control: Foot

Prop. Valve-Type: Height Sensing Split Point: Variable Ratio: .278

Plumbing Split Type: Diagonal

	Front	Rear
Brake Type:	Disc	Drum
Drum/Rotor Size:	mm	mm
Lining Size:	mm	mm
Lining Codes:	VX 5D EE	BX PM FE / BX RY FE
Lining Attachment:	Rivet	Rivet
Wheel Cyl/Piston dia:		

Weights	Frt	Rear	Total
Curb Weight	893 kg	647 kg	1540 kg
Test Weight LLVW	998 kg	714 kg	1712 kg
Test Weight GVW	1107 kg	1107 kg	2214 kg

Center of Gravity -

	Curb	LLVW	GVW
Height Above Ground	683 mm	692 mm	667 mm
Aft of Front Axle	1195 mm	1186 mm	1422 mm

Moments of Inertia (ft-lb/sec^2)	CURB	LLVW	GVW
Roll (About X Axis):	618.4	1148.2	782.5
Pitch (About Y Axis):	2300.5	2420.9	2898.5
Yaw (About Z Axis):	2589.4	2713.7	2935.5

Vehicle Maximum Speed: 142 km/h

Comments:

Summary of Performance to Modified Harmonized Brake Test Procedure

Vehicle Dodge Caravan Tested by VRTC

Date Test Completed 10/21/87 80% V_{max} = 113 km/h

Service Brake and Partial Failure Tests (Results for "best" stops)

	Laden				Unladen			
	100 km/h in neutral		80% V_{max} in gear		100 km/h in neutral		80% V_{max} in gear	
	SD (m)	PF_{max} (N)	SD (m)	PF_{max} (N)	SD (m)	PF_{max} (N)	SD (m)	PF_{max} (N)
Full Service Braking								
Engine On:	61	427	78	498	51	445	67	400
Engine Off:	58	485	NA	NA	NA	NA	NA	NA
Post Fade:	57	489	NA	NA	NA	NA	NA	NA
Partial Failures (Engine On):								
Circuit #1 Failed:	113	480	NA	NA	108	454	NA	NA
Circuit #2 Failed:	114	485	NA	NA	122	325	NA	NA
Anti-lock Failed:	NA	NA	NA	NA	NA	NA	NA	NA
Variable Prop. Valve Failed:	63	NA	NA	NA	61	NA	NA	NA
Power Unit/Assist Failed:	161	494	NA	NA	NA	NA	NA	NA

Adhesion Utilization

Low Coefficient Effectiveness

	SD (m)	PF_{max} (N)
Laden	26	196
Unladen	25	214

Axle Lock Sequence

	Balanced	Front	Rear
20 SN:			
Laden		X	
Unladen		X	
50 SN:			
Laden		X	
Unladen		X	

Parking Brake Tests

20% Grade

Control Force to Hold:

Uphill 365 N

Downhill 311 N

Dynamic Test

Results for Best Stop:

SD 72 m

Final Decel 3.96 m/s^2

PF_{max} 391 N

Fade and Recovery Series

Baseline: Best Stop SD 61 m Avg PF 258 N

Heating: Stops 1-15 PF_{max} 138 N

Stops 1-15 Min Decel Sus 2.90 m/s^2

Stop 15 Initial Temp (C)

LF 396 RF 440 LR 168 RR 116

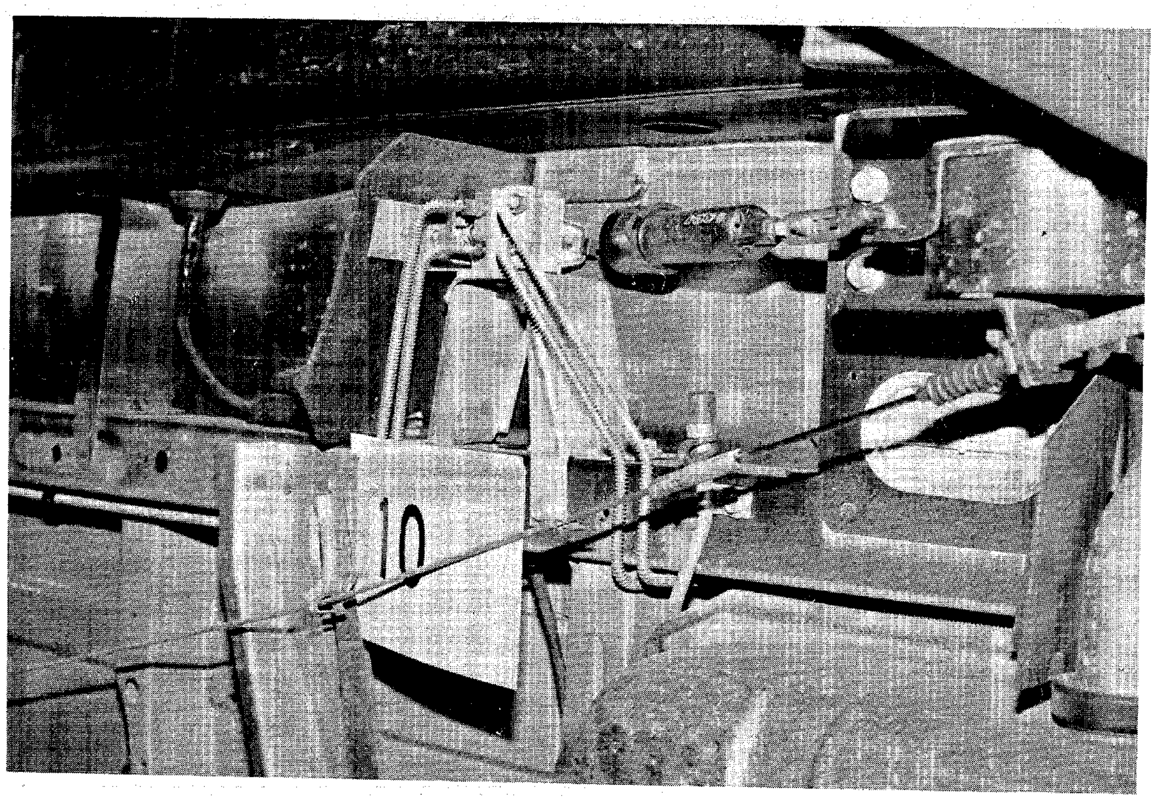
Hot Stop: SD 80 m PF_{max} 249 N

Recovery: Stops 1-4 PF_{max} 107 N

Recovery Stop: SD 66 m PF_{max} 249 N

(Rev. 2/6/87)

1987 Dodge Caravan



Dodge Caravan Height Sensing Proportioning Valve

Test Vehicle Information/Specifications

Vehicle Type: Minivan　Wheelbase: 2243 mm

Manufacturer: Toyota　Model: LE

VIN: JT3YR26W1H5041062　Production Date: 6/87

GVWR: 2155 kg GAWR - Frt: 1154 kg Rear: 1154 kg

Engine-Type: Gas　No. Cyl: 4　Disp: 2.2 l

Transmission-Type: Automatic　Fwd Spds: 4　Drive Axle:

Tires-Mfgr: Yokohama　Style: Radial

Size: P195/75 R14　Test Press - Frt: 2.4 bar Rear: 2.4 bar

Grade	LF	RF	LR	RR
Treadwear:	220	220	220	220
Traction:	B	B	B	B
Temperature:	B	B	B	B
Serial Number:	LV5217	LV5217	LV5217	LV5217
Estimated Mileage:	150	150	150	150

Brake System - Booster-Type: Vacuum

Parking Brake-Type: Rear Brake　Control: Hand

Prop. Valve-Type: Height Sensing　Split Point: Variable　Ratio:

Plumbing Split Type: Front/Rear

	Front	Rear
Brake Type:	Disc	Drum
Drum/Rotor Size:	255 mm	254 mm
Lining Size:	114x48x10 mm	244x50x5 mm
Lining Codes:	AK 3405 FF	B701A FE
Lining Attachment:	Bonded	Bonded
Wheel Cyl/Piston dia:	60.33	20.64

Weights - Curb Weight - Frt: 878 kg Rear: 633 kg Total: 1511 kg

Test Weight LLVW - Frt: 1084 kg Rear: 618 kg Total: 1702 kg

Test Weight GVW - Frt: 1082 kg Rear: 1074 kg Total: 2156 kg

Center of Gravity -

Height Above Ground - Curb: 684 mm LLVW: 685 mm GVW: 712 mm

Aft of Front Axle - Curb: 940 mm LLVW: 814 mm GVW: 117 mm

Moments of Inertia (ft-lb/sec^2)	CURB	LLVW	GVW
Roll (About X Axis):	499.1	635.3	657.5
Pitch (About Y Axis):	1716.2	2001.3	2480.6
Yaw (About Z Axis):	1777.9	1953.1	2601.2

Vehicle Maximum Speed: 135 km/h

Comments:

Summary of Performance to Modified Harmonized Brake Test Procedure

Vehicle Toyota Van   Tested by VRTC

Date Test Completed 9-9-87   80% V_{max} = 108 km/h

Service Brake and Partial Failure Tests (Results for "best" stops)

	Laden				Unladen			
	100 km/h in neutral		80% V_{max} in gear		100 km/h in neutral		80% V_{max} in gear	
	SD (m)	PF_{max} (N)	SD (m)	PF_{max} (N)	SD (m)	PF_{max} (N)	SD (m)	PF_{max} (N)
Full Service Braking								
Engine On:	64	427	72	445	54	276	63	334
Engine Off:	57	445	NA	NA	NA	NA	NA	NA
Post Fade:	59	467	NA	NA	NA	NA	NA	NA
Partial Failures (Engine On):								
Circuit #1 Failed:	146	498	NA	NA	156	187	NA	NA
Circuit #2 Failed:	70	480	NA	NA	59	316	NA	NA
Anti-lock Failed:	NA	NA	NA	NA	NA	NA	NA	NA
Variable Prop. Valve Failed:	57	498	NA	NA	58	280	NA	NA
Power Unit/Assist Failed:	135	498	NA	NA	NA	NA	NA	NA

Adhesion Utilization

Low Coefficient Effectiveness

	SD (m)	PF_{max} (N)
Laden	28	151
Unladen	24	173

Axle Lock Sequence

	Balanced	Front	Rear
20 SN:			
Laden		X	
Unladen		X	
50 SN:			
Laden		X	
Unladen		X	

Parking Brake Tests

20% Grade

Control Force to Hold:

Uphill 254 N

Downhill 222 N

Dynamic Test

Results for Best Stop:

SD 58 m

Final Decel 2.74 m/s^2

PF_{max} 391 N

Fade and Recovery Series

Baseline: Best Stop SD 64 m Avg PF 249 N

Heating: Stops 1-15 PF_{max} 120 N

Stops 1-15 Min Decel Sus 2.90 m/s^2

Stop 15 Initial Temp (C)

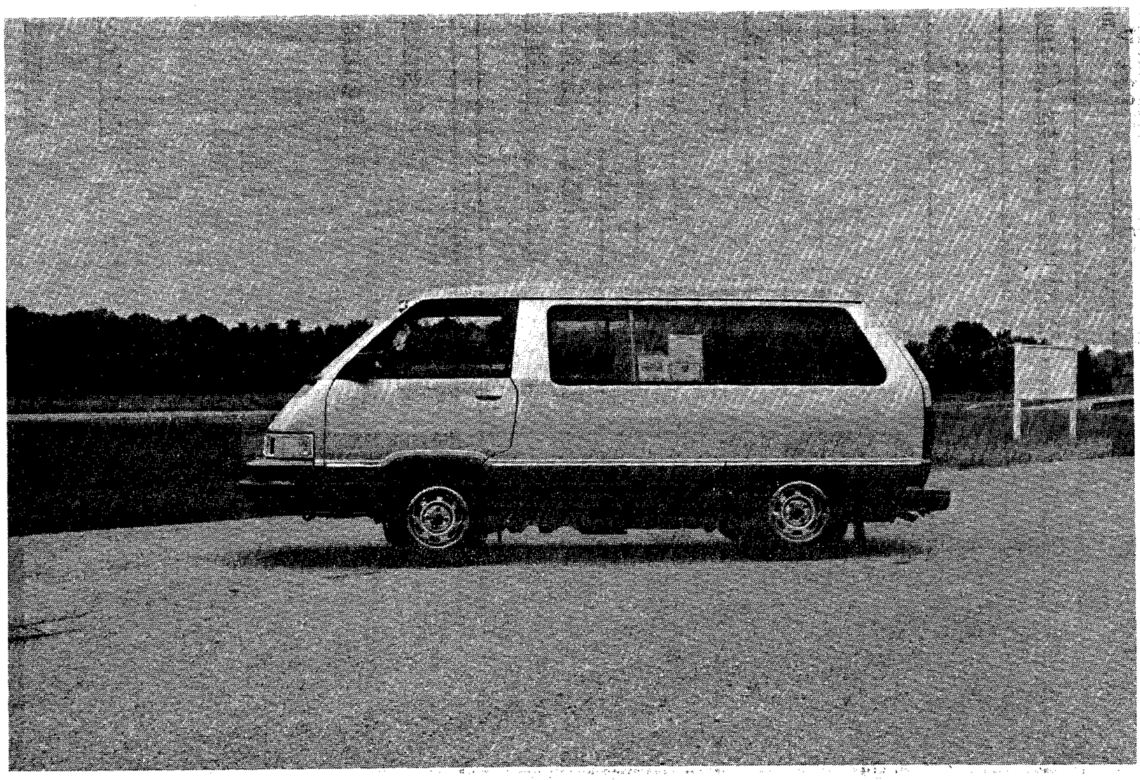
LF 432 RF 432 LR 196 RR 190

Hot Stop: SD 73 m PF_{max} 245 N

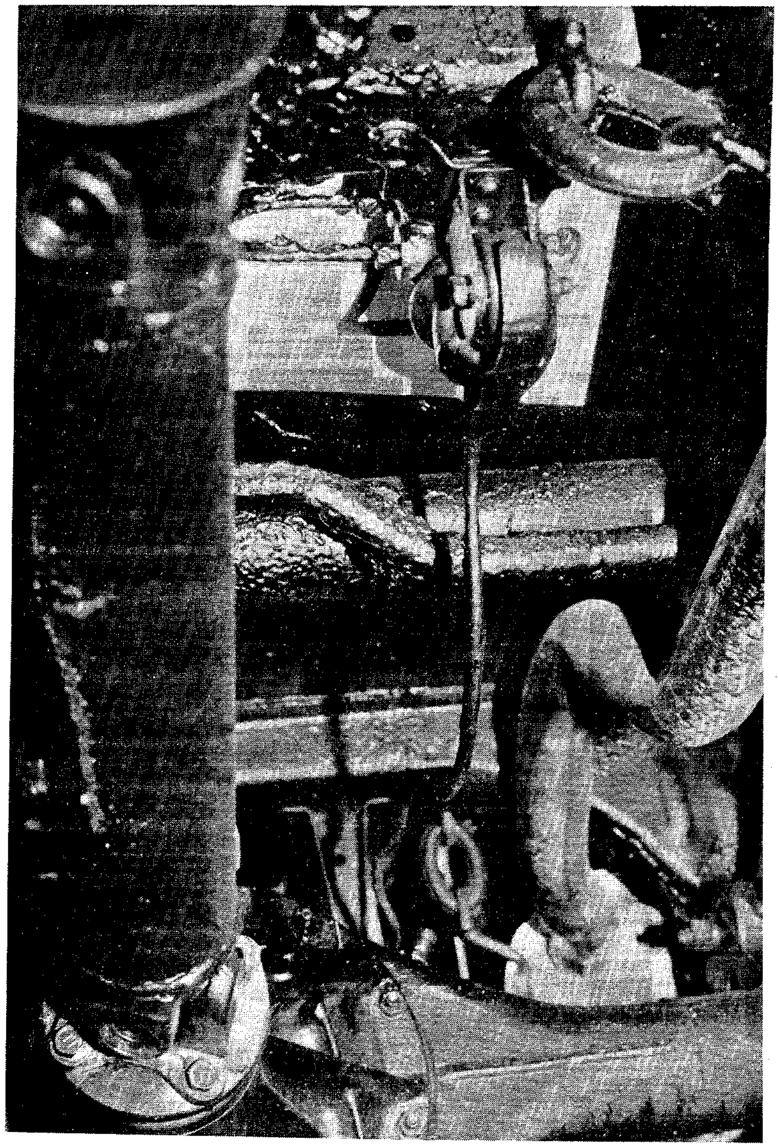
Recovery: Stops 1-4 PF_{max} 124 N

Recovery Stop: SD 66 m PF_{max} 231 N

(Rev. 2/6/87)



1987 Toyota Van



Toyota Van Height Sensing Proportioning Valve

Test Vehicle Information/Specifications

Vehicle Type: Van   Wheelbase: 3340 mm

Manufacturer: Chevrolet   Model: Astro

VIN: 1GNDM1527HB113938   Production Date: 9/86

GVWR: 2378 kg   GAWR - Frt: 1225 kg   Rear: 1315 kg

Engine-Type: Gas   No. Cyl: 6   Disp: 4.3 l

Transmission-Type: Auto   Fwd Spds: 4   Drive Axle: Rear

Tires-Mfgr: Goodyear   Style: Radial

Size: P205/75 R15   Test Press - Frt: ____ bar   Rear: ____ bar

Grade	LF	RF	LR	RR
Treadwear:	280	280	280	280
Traction:	A	A	A	A
Temperature:	B	B	B	B
Serial Number:				
Estimated Mileage:	800	800	800	800

Brake System - Booster-Type: Vacuum

Parking Brake-Type: Rear Shoes   Control: Foot

Prop. Valve-Type: Fixed   Split Point: 295   Ratio: .285

Plumbing Split Type: Front/Rear

	Front	Rear
Brake Type:	Disc	Drum
Drum/Rotor Size:	mm	mm
Lining Size:	mm	mm
Lining Codes:	117 FE	241 FG
Lining Attachment:	Rivet	Rivet
Wheel Cyl/Piston dia:		

Weights

	Frt	Rear	Total
Curb Weight	997 kg	780 kg	1777 kg
Test Weight LLVW	1148 kg	837 kg	1985 kg
Test Weight GVW	1150 kg	1225 kg	2375 kg

Center of Gravity -

	Curb	LLVW	GVW
Height Above Ground	749 mm	749 mm	805 mm
Aft of Front Axle	1466 mm	1408 mm	1723 mm

Moments of Inertia (ft-lb/sec^2)	CURB	LLVW	GVW
Roll (About X Axis):	NA	NA	NA
Pitch (About Y Axis):	NA	NA	NA
Yaw (About Z Axis):	NA	NA	NA

Vehicle Maximum Speed: 163 km/h

Comments:

Summary of Performance to Modified Harmonized Brake Test Procedure

Vehicle: Chevrolet Astro Tested by: VRTC

Date Test Completed: 10/14/87 80% V_{max} = 130 km/h

Service Brake and Partial Failure Tests (Results for "best" stops)

	Laden				Unladen			
	100 km/h in neutral		80% V_{max} in gear		100 km/h in neutral		80% V_{max} in gear	
Full Service Braking	SD (m)	PF_{max} (N)	SD (m)	PF_{max} (N)	SD (m)	PF_{max} (N)	SD (m)	PF_{max} (N)
Engine On:	54	462	92	492	51	498	82	498
Engine Off:	59	445	NA	NA	NA	NA	NA	NA
Post Fade:	59	374	NA	NA	NA	NA	NA	NA
Partial Failures (Engine On):								
Circuit #1 Failed:	72	445	NA	NA	62	480	NA	NA
Circuit #2 Failed:	135	498	NA	NA	139	485	NA	NA
Anti-lock Failed:	NA	NA	NA	NA	NA	NA	NA	NA
Variable Prop. Valve Failed:	NA	NA	NA	NA	NA	NA	NA	NA
Power Unit/Assist Failed:	144	498	NA	NA	NA	NA	NA	NA

Adhesion Utilization

Low Coefficient Effectiveness

	SD (m)	PF_{max} (N)
Laden	29	222
Unladen	22	285

Axle Lock Sequence

	Balanced	Front	Rear
20 SN:			
Laden		X	
Unladen		X	
50 SN:			
Laden		X	
Unladen		X	

Parking Brake Tests

20% Grade

Control Force to Hold:

Uphill 462 N

Downhill 445 N

Dynamic Test

Results for Best Stop:

SD 50 m

Final Decel 3.05 m/s^2

PF_{max} 498 N

Fade and Recovery Series

Baseline: Best Stop SD 54 m Avg PF 391 N

Heating: Stops 1-15 PF_{max} 116 N

Stops 1-15 Min Decel Sus 3.05 m/s^2

Stop 15 Initial Temp (C)

LF 377 RF 377 LR 171 RR 199

Hot Stop: SD 61 m PF_{max} 378 N

Recovery: Stops 1-4 PF_{max} 107 N

Recovery Stop: SD 56 m PF_{max} 391 N

(Rev. 2/6/87)

Test Vehicle Information/Specifications

Vehicle Type: Van   Wheelbase: 3505 mm

Manufacturer: Ford   Model: E-250

VIN: 1FTEE24H1HHA11007   Production Date: 8/86

GVWR: 3265 kg GAWR - Frt: 1406 kg Rear: 1929 kg

Engine-Type: Gas   No. Cyl: 8   Disp: 5.73 l

Transmission-Type: Automatic   Fwd Spds: ____   Drive Axle: Rear

Tires-Mfgr: Michelin   Style: Radial XC144

Size: LT215/85R16   Test Press - Frt: 4.5 bar Rear: 4.5 bar

Grade	LF	RF	LR	RR
Treadwear:				
Traction:				
Temperature:				
Serial Number:	GD1189	AE274	AE282	GD1189
Estimated Mileage:	5500	5500	5500	5500

Brake System -

Booster-Type: Vacuum

Parking Brake-Type: Rear Shoes   Control: Foot

Prop. Valve-Type: Height Sensing Split Point: ____   Ratio: ____

Plumbing Split Type: Front/Rear

	Front	Rear
Brake Type:	Disc	Drum
Drum/Rotor Size:	318 x 32 mm	305 x 76 mm
Lining Size:	mm	mm
Lining Codes:	Ray 7033-4 FF	Pri BX-UB-FE Sec BX-UC-DD
Lining Attachment:		
Wheel Cyl/Piston dia:		

Weights - Curb Weight - Frt: NA kg Rear: NA kg Total: NA kg

Test Weight LLVW - Frt: 1234 kg Rear: 1016 kg Total: 2250 kg

Test Weight GVW - Frt: 1379 kg Rear: 1882 kg Total: 3261 kg

Center of Gravity -

Height Above Ground - Curb: NA mm LLVW: 771 mm GVW: 734 mm

Aft of Front Axle - Curb: NA mm LLVW: 1583 mm GVW: 2023 mm

Moments of Inertia (ft-lb/sec^2)	CURB	LLVW	GVW
Roll (About X Axis):	NA	NA	NA
Pitch (About Y Axis):	NA	NA	NA
Yaw (About Z Axis):	NA	NA	NA

Vehicle Maximum Speed: 158 km/h

Comments: Height Sensing Valve - Two Stage

Summary of Performance to Modified Harmonized Brake Test Procedure

Vehicle Ford E-250 Tested by VRTC

Date Test Completed 6/17/87 80% V_{max} = 126 km/h

Service Brake and Partial Failure Tests (Results for "best" stops)

	Laden				Unladen			
	100 km/h in neutral		80% V_{max} in gear		100 km/h in neutral		80% V_{max} in gear	
Full Service Braking	SD (m)	PF_{max} (N)	SD (m)	PF_{max} (N)	SD (m)	PF_{max} (N)	SD (m)	PF_{max} (N)
Engine On:	59	445	93	445	55	436	91	427
Engine Off:	58	374	NA	NA	NA	NA	NA	NA
Post Fade:	59	445	NA	NA	NA	NA	NA	NA
Partial Failures (Engine On):								
Circuit #1 Failed:	129	480	NA	NA	144	498	NA	NA
Circuit #2 Failed:	81	436	NA	NA	73	360	NA	NA
Anti-lock Failed:	NA	NA	NA	NA	NA	NA	NA	NA
Variable Prop. Valve Failed:	63	445	NA	NA	55	480	NA	NA
Power Unit/Assist Failed:	144	498	NA	NA	NA	NA	NA	NA

Adhesion Utilization

Low Coefficient Effectiveness

	SD (m)	PF_{max} (N)
Laden	29	214
Unladen	27	138

Axle Lock Sequence

	Balanced	Front	Rear
20 SN:			
Laden		X	
Unladen		X	
50 SN:			
Laden			X
Unladen		X	

Parking Brake Tests

20% Grade

Control Force to Hold:

Uphill 462 N

Downhill 427 N

Dynamic Test

Results for Best Stop:

SD 43 m

Final Decel 3.96 m/s^2

PF_{max} 445 N

Fade and Recovery Series

Baseline: Best Stop SD 59 m Avg PF 285 N

Heating: Stops 1-15 PF_{max} 209 N

Stops 1-15 Min Decel Sus 3.05 m/s^2

Stop 15 Initial Temp (C)

LF 466 RF 490 LR 124 RR 157

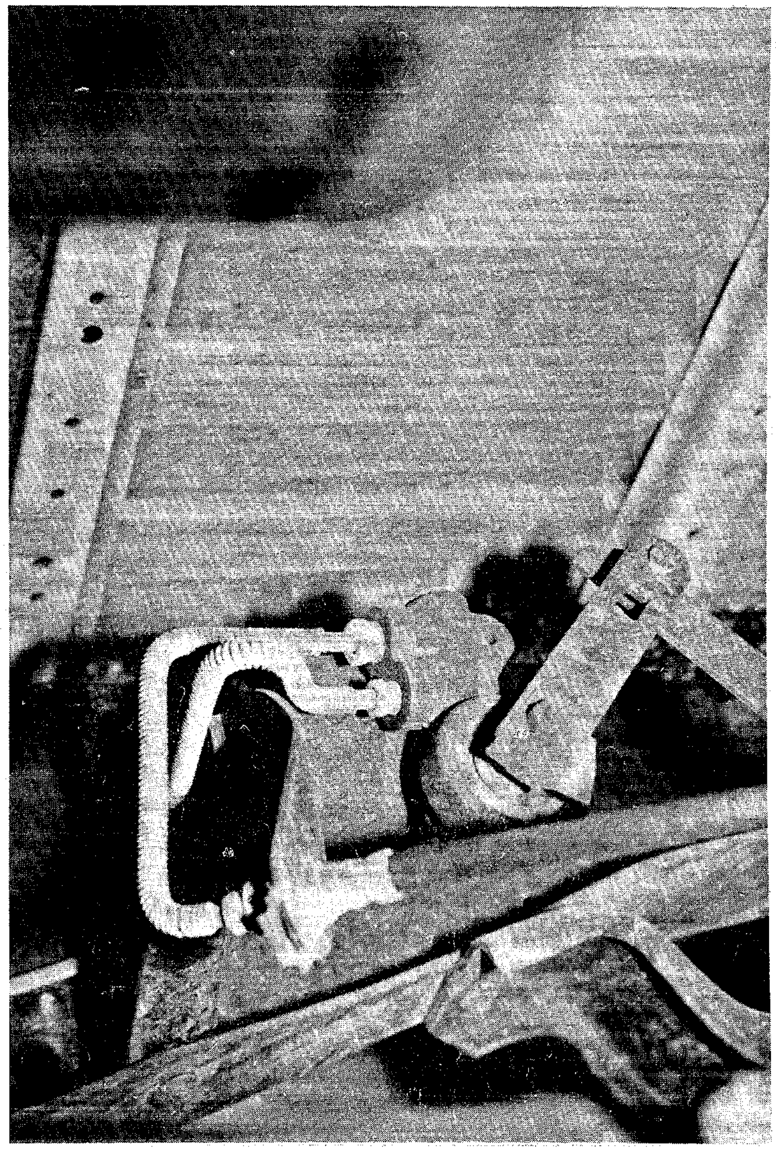
Hot Stop: SD 104 m PF_{max} 271 N

Recovery: Stops 1-4 PF_{max} 142 N

Recovery Stop: SD 71 m PF_{max} 267 N

(Rev. 2/6/87)

1986 Ford E-250 Van



Ford E-250 Height Sensing Proportioning Valve

Test Vehicle Information/Specifications

Vehicle Type: King Cab Pickup   Wheelbase: 2950 mm

Manufacturer: Nissan   Model:

VIN: JN6ND1652HW011015   Production Date: 2/87

GVWR: 1996 kg   GAWR - Frt: 998 kg   Rear: 1154 kg

Engine-Type: Gas   No. Cyl: 4   Disp: 2.4 l

Transmission-Type: Automatic   Fwd Spds: 3   Drive Axle: Rear

Tires-Mfgr: Toyo   Style: Radial

Size: P195/75 R14   Test Press - Frt: 2.4 bar   Rear: 2.4 bar

Grade	LF	RF	LR	RR
Treadwear:	200	200	200	200
Traction:	B	B	B	B
Temperature:	B	B	B	B
Serial Number:	MPC047	MPC047	MPC047	MPC047
Estimated Mileage:	1000	1000	1000	1000

Brake System - Booster-Type: Vacuum

Parking Brake-Type: Rear Brake   Control: Hand

Prop. Valve-Type: Variable   Split Point: Ratio:

Plumbing Split Type: Front/Rear

	Front	Rear
Brake Type:	Disc	Drum
Drum/Rotor Size:	258x26 mm	260 mm
Lining Size:	146.6x48.5x10 mm	249.6x50.0x5.5 mm
Lining Codes:	HITACHI HP14EE	AKEBONO B701FE
Lining Attachment:	Bonded	Bonded
Wheel Cyl/Piston dia:	42.8	25.4

Weights	Frt	Rear	Total
Curb Weight	758 kg	630 kg	1388 kg
Test Weight LLVW	871 kg	698 kg	1569 kg
Test Weight GVW	916 kg	1080 kg	1996 kg

Center of Gravity -

	Curb	LLVW	GVW
Height Above Ground	608 mm	606 mm	635 mm
Aft of Front Axle	1339 mm	1312 mm	1596 mm

Moments of Inertia (ft-lb/sec^2)	CURB	LLVW	GVW
Roll (About X Axis):	370.7	454.1	556.6
Pitch (About Y Axis):	1998.2	2318.3	2795.3
Yaw (About Z Axis):	2272.4	2526.7	2955.4

Vehicle Maximum Speed: 150 km/h

Comments: Deceleration sensing prop. valve

Summary of Performance to Modified Harmonized Brake Test Procedure

Vehicle Nissan Truck Tested by VRTC

Date Test Completed 7/24/87 80% V_{max} = 120 km/h

Service Brake and Partial Failure Tests (Results for "best" stops)

	Laden				Unladen			
	100 km/h in neutral		80% V_{max} in gear		100 km/h in neutral		80% V_{max} in gear	
	SD (m)	PF_{max} (N)	SD (m)	PF_{max} (N)	SD (m)	PF_{max} (N)	SD (m)	PF_{max} (N)
Full Service Braking								
Engine On:	65	462	97	356	57	436	80	400
Engine Off:	69	445	NA	NA	NA	NA	NA	NA
Post Fade:	65	294	NA	NA	NA	NA	NA	NA
Partial Failures (Engine On):								
Circuit #1 Failed:	88	334	NA	NA	76	240	NA	NA
Circuit #2 Failed:	118	480	NA	NA	127	249	NA	NA
Anti-lock Failed:	NA	NA	NA	NA	NA	NA	NA	NA
Variable Prop. Valve Failed:	52	436	NA	NA	67	142	NA	NA
Power Unit/Assist Failed:	131	494	NA	NA	NA	NA	NA	NA

Adhesion Utilization

Low Coefficient Effectiveness

	SD (m)	PF_{max} (N)
Laden	25	156
Unladen	26	116

Axle Lock Sequence

	Balanced	Front	Rear
20 SN:			
Laden		X	
Unladen		X	
50 SN:			
Laden		X	
Unladen		X	

Parking Brake Tests

20% Grade

Control Force to Hold:

Uphill 222 N

Downhill 222 N

Dynamic Test

Results for Best Stop:

SD 54 m

Final Decel 3.05 m/s^2

PF_{max} 400 N

Fade and Recovery Series

Baseline: Best Stop SD 65 m Avg PF 258 N

Heating: Stops 1-15 PF_{max} 111 N

Stops 1-15 Min Decel Sus 3.05 m/s^2

Stop 15 Initial Temp (C)

LF 496 RF 516 LR 224 RR 243

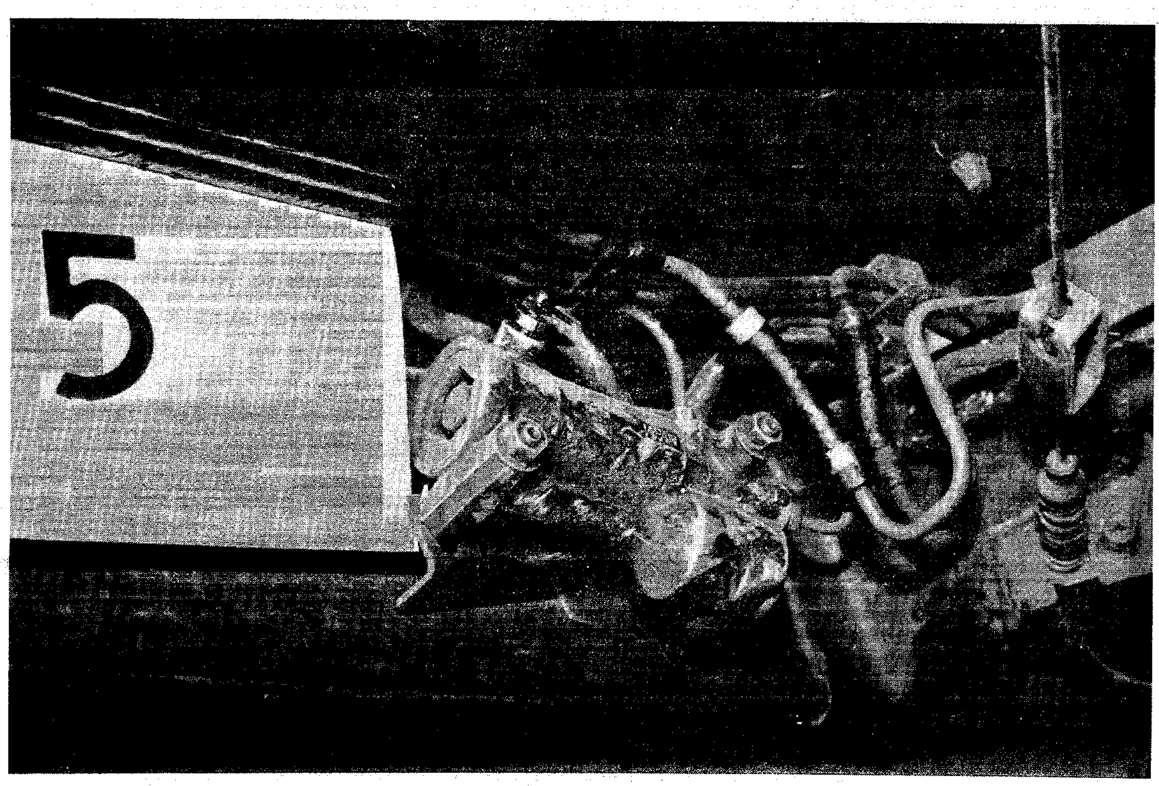
Hot Stop: SD 72 m PF_{max} 258 N

Recovery: Stops 1-4 PF_{max} 124 N

Recovery Stop: SD 68 m PF_{max} 258 N

(Rev. 2/6/87)

1987 Nissan Truck



Nissan Truck Deceleration Sensing Proportioning Valve

Test Vehicle Information/Specifications

Vehicle Type: 4WD Pickup   Wheelbase: 3124 mm

Manufacturer: Chevrolet   Model: S-10

VIN: 1GCDT14R2H2213412   Production Date: 4/87

GVWR: 2314 kg   GAWR - Frt: 1225 kg   Rear: 1225 kg

Engine-Type: Gas   No. Cyl: 6   Disp: 2.8 l

Transmission-Type: Automatic   Fwd Spds: 4   Drive Axle:

Tires-Mfgr: General   Style: Radial

Size: P205/75 R15   Test Press - Frt: 2.4 bar   Rear: 2.4 bar

Grade	LF	RF	LR	RR
Treadwear:	NA	NA	NA	NA
Traction:	NA	NA	NA	NA
Temperature:	NA	NA	NA	NA
Serial Number:	NA	NA	NA	NA
Estimated Mileage:	650	650	650	650

Brake System - Booster-Type: Vacuum

Parking Brake-Type: Rear Shoes   Control: Foot

Prop. Valve-Type: Fixed   Split Point: 298   Ratio: .48

Plumbing Split Type: Front/Rear

	Front	Rear
Brake Type:	Rotor	Drum
Drum/Rotor Size:	mm	mm
Lining Size:	mm	mm
Lining Codes:	117 FE	235 FE / 224 FF
Lining Attachment:	Rivet	Rivet
Wheel Cyl/Piston dia:		

Weights - Curb Weight - Frt: 967 kg   Rear: 639 kg   Total: 1606 kg

Test Weight LLVW - Frt: 1084 kg   Rear: 748 kg   Total: 1832 kg

Test Weight GVW - Frt: 1148 kg   Rear: 1161 kg   Total: 2309 kg

Center of Gravity -

Height Above Ground - Curb: 618 mm   LLVW: 639 mm   GVW: 697 mm

Aft of Front Axle - Curb: 1243 mm   LLVW: 1276 mm   GVW: 1571 mm

Moments of Inertia (ft-lb/sec^2)	CURB	LLVW	GVW
Roll (About X Axis):	405.0	485.8	537.5
Pitch (About Y Axis):	2473.0	2755.2	3071.3
Yaw (About Z Axis):	2686.0	2903.5	3685.0

Vehicle Maximum Speed: 151 km/h

Comments:

Summary of Performance to Modified Harmonized Brake Test Procedure

Vehicle Chevrolet S-10 Tested by VRTC

Date Test Completed 9-29-87 80% V_{max} = 121 km/h

Service Brake and Partial Failure Tests (Results for "best" stops)

	Laden				Unladen			
	100 km/h in neutral		80% V_{max} in gear		100 km/h in neutral		80% V_{max} in gear	
	SD (m)	PF_{max} (N)	SD (m)	PF_{max} (N)	SD (m)	PF_{max} (N)	SD (m)	PF_{max} (N)
Full Service Braking								
Engine On:	61	498	88	498	54	436	77	374
Engine Off:	62	498	NA	NA	NA	NA	NA	NA
Post Fade:	60	498	NA	NA	NA	NA	NA	NA
Partial Failures (Engine On):								
Circuit #1 Failed:	80	445	NA	NA	67	400	NA	NA
Circuit #2 Failed:	182	498	NA	NA	161	480	NA	NA
Anti-lock Failed:	NA	NA	NA	NA	NA	NA	NA	NA
Variable Prop. Valve Failed:	NA	NA	NA	NA	NA	NA	NA	NA
Power Unit/Assist Failed:	180	498	NA	NA	NA	NA	NA	NA

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Adhesion Utilization

Low Coefficient Effectiveness

	SD (m)	PF_{max} (N)
Laden	35	116
Unladen	26	124

Axle Lock Sequence

	Balanced	Front	Rear
20 SN:			
Laden		X	
Unladen		X	
50 SN:			
Laden		X	
Unladen		X	

Parking Brake Tests

20% Grade

Control Force to Hold:

Uphill .391 N

Downhill 311 N

Dynamic Test

Results for Best Stop:

SD 66 m

Final Decel 3.05 m/s^2

PF_{max} 498 N

Fade and Recovery Series

Baseline: Best Stop SD 61 m Avg PF 471 N

Heating: Stops 1-15 PF_{max} 107 N

Stops 1-15 Min Decel Sus 2.90 m/s^2

Stop 15 Initial Temp (C)

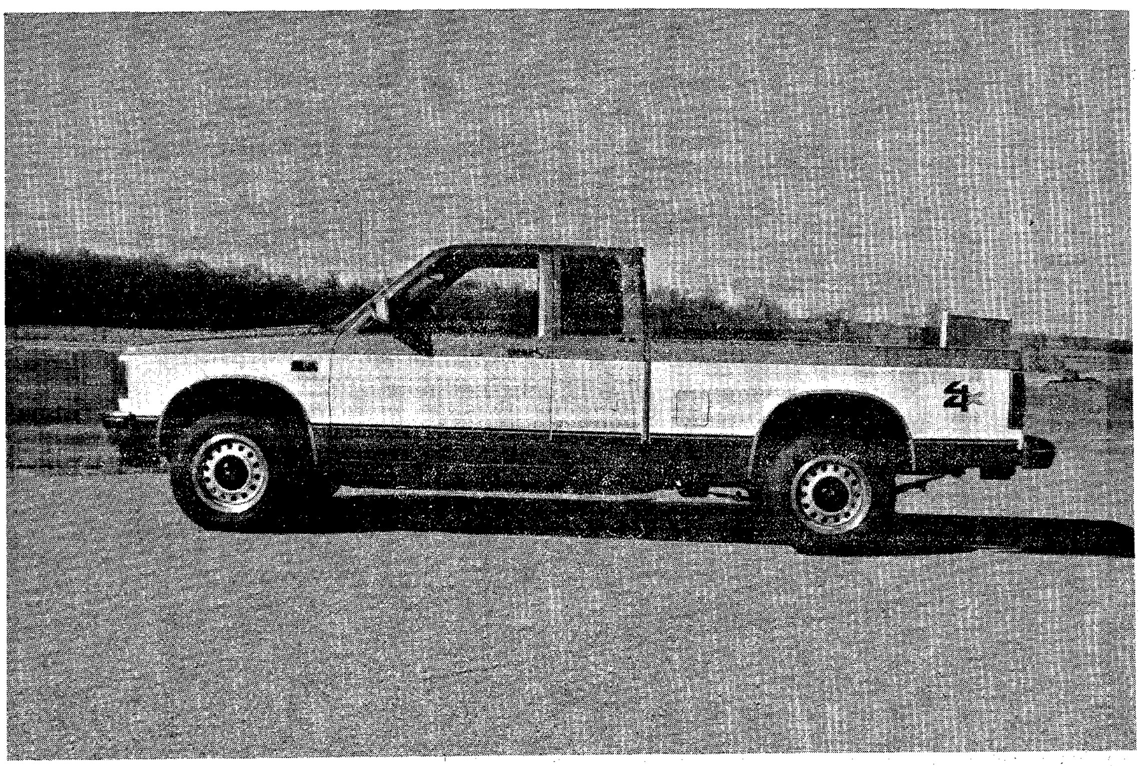
LF 510 RF 499 LR 166 RR 154

Hot Stop: SD 75 m PF_{max} 454 N

Recovery: Stops 1-4 PF_{max} 116 N

Recovery Stop: SD 65 m PF_{max} 462 N

(Rev. 2/6/87)



1987 Chevrolet S-10

Test Vehicle Information/Specifications

Vehicle Type: Pickup Wheelbase: 2743 mm

Manufacturer: Ford Model: Ranger

VIN: IFTBRIOA3FUB74109 Production Date: 1985

GVWR: 1724 kg GAWR - Frt: 832 kg Rear: 931 kg

Engine-Type: Gas No. Cyl: 4 Disp: 2.3 l

Transmission-Type: Standard Fwd Spds: 5 Drive Axle: Rear

Tires-Mfgr: Goodyear Style: Radial

Size: P185/75 R14 Test Press - Frt: 2.4 bar Rear: 2.4 bar

Grade	LF	RF	LR	RR
Treadwear:	NA	NA	NA	NA
Traction:	NA	NA	NA	NA
Temperature:	NA	NA	NA	NA
Serial Number:	NA	NA	NA	NA
Estimated Mileage:	5000	5000	5000	5000

Brake System - Booster-Type: Vacuum

Parking Brake-Type: Rear Shoes Control: Foot

Prop. Valve-Type: None Split Point: -- Ratio: .--

Plumbing Split Type: Front/Rear

	Front	Rear
Brake Type:	Rotor	Drum
Drum/Rotor Size:	mm	mm
Lining Size:	mm	mm
Lining Codes:	641 FF	6012 FF
Lining Attachment:	Rivet	Rivet
Wheel Cyl/Piston dia:		

Weights - Curb Weight - Frt: 703 kg Rear: 535 kg Total: 1238 kg

Test Weight LLVW - Frt: 776 kg Rear: 626 kg Total: 1402 kg

Test Weight GVW - Frt: 810 kg Rear: 914 kg Total: 1724 kg

Center of Gravity -

Height Above Ground - Curb: 619 mm LLVW: 658 mm GVW: 659 mm

Aft of Front Axle - Curb: 1185 mm LLVW: 1225 mm GVW: 1454 mm

Moments of Inertia (ft-lb/sec^2)	CURB	LLVW	GVW
Roll (About X Axis):	327.5	384.4	437.8
Pitch (About Y Axis):	1582.1	1722.5	2007.7
Yaw (About Z Axis):	1699.6	1848.0	2326.6

Vehicle Maximum Speed: 145 km/h

Comments:

Summary of Performance to Modified Harmonized Brake Test Procedure

Vehicle: Ford Ranger Tested by: VRTC

Date Test Completed: 2/10/87 80% V_{max} = 116 km/h

Service Brake and Partial Failure Tests (Results for "best" stops)

	Laden				Unladen			
	100 km/h in neutral		80% V_{max} in gear		100 km/h in neutral		80% V_{max} in gear	
Full Service Braking	SD (m)	PF_{max} (N)	SD (m)	PF_{max} (N)	SD (m)	PF_{max} (N)	SD (m)	PF_{max} (N)
Engine On:	50	196	68	249	60	124	69	124
Engine Off:	46	298	NA	NA	NA	NA	NA	NA
Post Fade:	47	267	NA	NA	NA	NA	NA	NA
Partial Failures (Engine On):								
Circuit #1 Failed:	78	267	NA	NA	68	214	NA	NA
Circuit #2 Failed:	104	489	NA	NA	124	214	NA	NA
Anti-lock Failed:	NA	NA	NA	NA	NA	NA	NA	NA
Variable Prop. Valve Failed:	NA	NA	NA	NA	NA	NA	NA	NA
Power Unit/Assist Failed:	62	498	NA	NA	NA	NA	NA	NA

Adhesion Utilization

Low Coefficient Effectiveness

	SD (m)	PF_{max} (N)
Laden	30	111
Unladen	24	102

Axle Lock Sequence

	Balanced	Front	Rear
20 SN:			
Laden		X	
Unladen		X	
50 SN:			
Laden			X
Unladen			X

Parking Brake Tests

20% Grade

Control Force to Hold:

Uphill 285 N

Downhill 218 N

Dynamic Test

Results for Best Stop:

SD 49 m

Final Decel 3.96 m/s^2

PF_{max} 302 N

Fade and Recovery Series

Baseline: Best Stop SD 50 m Avg PF 129 N

Heating: Stops 1-15 PF_{max} 53 N

Stops 1-15 Min Decel Sus 2.90 m/s^2

Stop 15 Initial Temp (C)

LF 288 RF 357 LR 177 RR 160

Hot Stop: SD 73 m PF_{max} 129 N

Recovery: Stops 1-4 PF_{max} 58 N

Recovery Stop: SD 61 m PF_{max} 129 N

(Rev. 2/6/87)

1985 Ford Ranger

Test Vehicle Information/Specifications

Vehicle Type: Pickup Wheelbase: 2967 mm

Manufacturer: Ford Model: F-150

VIN: 1FTCF15H4HLA48109 Production Date: 3/87

GVWR: 2177 kg GAWR - Frt: 1202 kg Rear: 1309 kg

Engine-Type: Gas No. Cyl: 8 Disp: 5.8 l

Transmission-Type: Auto Fwd Spds: ______ Drive Axle: Rear

Tires-Mfgr: Firestone Style: Supreme

Size: P215/75R15 Test Press - Frt: ______ bar Rear: ______ bar

Grade	LF	RF	LR	RR
Treadwear:	220	220	220	220
Traction:	B	B	B	B
Temperature:	B	B	B	B
Serial Number:	16394	16395	16395	16033
Estimated Mileage:	60	60	60	60

Brake System -

Booster-Type: Vacuum

Parking Brake-Type: Shoes of rear brake Control: Foot

Prop. Valve-Type: Fixed Split Point: ______ Ratio: ______

Plumbing Split Type: Front/Rear

	Front	Rear
Brake Type:	Disc	Drum
Drum/Rotor Size:	mm	mm
Lining Size:	mm	mm
Lining Codes:		
Lining Attachment:		
Wheel Cyl/Piston dia:		

Weights	Frt	Rear	Total
Curb Weight	1056 kg	663 kg	1719 kg
Test Weight LLVW	1152 kg	766 kg	1918 kg
Test Weight GVW	1061 kg	1175 kg	2236 kg

Center of Gravity -

	Curb	LLVW	GVW
Height Above Ground	704 mm	706 mm	734 mm
Aft of Front Axle	1144 mm	1185 mm	1559 mm

Moments of Inertia (ft-lb/sec^2)	CURB	LLVW	GVW
Roll (About X Axis):	627.7	858	951.2
Pitch (About Y Axis):	2571.6	3013.1	4185.3
Yaw (About Z Axis):	2768.8	2886.3	4435.5

Vehicle Maximum Speed: 169 km/h

Comments: Rear axle antilock

Summary of Performance to Modified Harmonized Brake Test Procedure

Vehicle Ford F-150 Tested by VRTC

Date Test Completed 5/26/87 80% V_{max} = 135 km/h

Service Brake and Partial Failure Tests (Results for "best" stops)

	Laden				Unladen			
	100 km/h in neutral		80% V_{max} in gear		100 km/h in neutral		80% V_{max} in gear	
Full Service Braking	SD (m)	PF_{max} (N)	SD (m)	PF_{max} (N)	SD (m)	PF_{max} (N)	SD (m)	PF_{max} (N)
Engine On:	58	258	96	280	52	320	94	302
Engine Off:	58	236	NA	NA	NA	NA	NA	NA
Post Fade:	56	245	NA	NA	NA	NA	NA	NA
Partial Failures (Engine On):								
Circuit #1 Failed:	198	489	NA	NA	201	480	NA	NA
Circuit #2 Failed:	75	231	NA	NA	64	262	NA	NA
Anti-lock Failed:	57	316	NA	NA	53	262	NA	NA
Variable Prop. Valve Failed:	NA	NA	NA	NA	NA	NA	NA	NA
Power Unit/Assist Failed:	73	498	NA	NA	NA	NA	NA	NA

Adhesion Utilization

Low Coefficient Effectiveness

	SD (m)	PF_{max} (N)
Laden	36	93
Unladen	32	93

Axle Lock Sequence

	Balanced	Front	Rear
20 SN:			
Laden		X	
Unladen		X	
50 SN:			
Laden		X	
Unladen		X	

*Run on 65 SN

Parking Brake Tests

20% Grade

Control Force to Hold:

Uphill 498 N

Downhill 485 N

Dynamic Test

Results for Best Stop:

SD 76 m

Final Decel 1.98 m/s^2

PF_{max} 498 N

Fade and Recovery Series

Baseline: Best Stop SD 58 m Avg PF 151 N

Heating: Stops 1-15 PF_{max} 76 N

Stops 1-15 Min Decel Sus 2.90 m/s^2

Stop 15 Initial Temp (C)

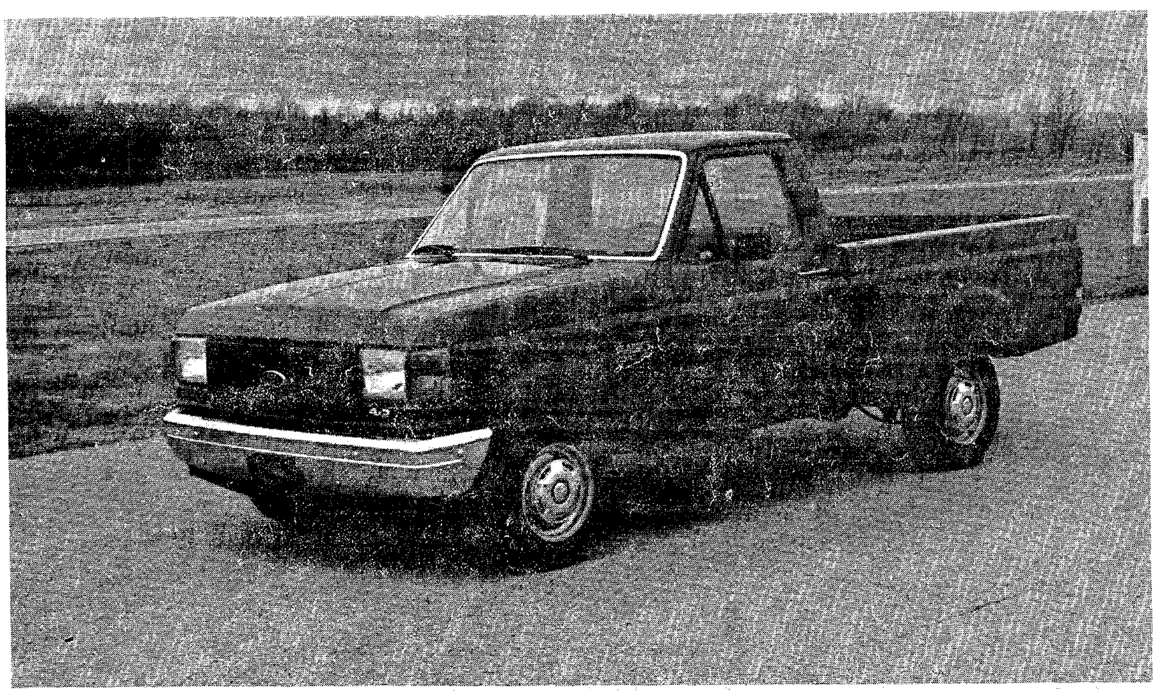
LF 377 RF 377 LR 196 RR 216

Hot Stop: SD 81 m PF_{max} 147 N

Recovery: Stops 1-4 PF_{max} 71 N

Recovery Stop: SD 66 m PF_{max} 142 N

(Rev. 2/6/87)



1987 Ford F-150

Test Vehicle Information/Specifications

Vehicle Type: Pickup Wheelbase: 3353 mm

Manufacturer: Chevrolet Model: C-1500

VIN: 1GCDC14H45Z146400 Production Date: 08/87

GVWR: 2540 kg GAWR - Frt: 1338 kg Rear: 1544 kg

Engine-Type: Gas No. Cyl: 8 Disp: 5.0 l

Transmission-Type: Auto Fwd Spds: 4 Drive Axle: Rear

Tires-Mfgr: Uniroyal Style: Radial

Size: P235/75 R15 Test Press - Frt: 2.4 bar Rear: 2.4 bar

Grade	LF	RF	LR	RR
Treadwear:	280	280	280	280
Traction:	B	B	B	B
Temperature:	C	C	C	C
Serial Number:	--	--	--	--
Estimated Mileage:	800	800	800	800

Brake System - Booster-Type: Vacuum

Parking Brake-Type: Rear Shoes Control: Foot

Prop. Valve-Type: Fixed Split Point: 460 Ratio: .445

Plumbing Split Type: Front/Rear

	Front	Rear
Brake Type:	Disc	Drum
Drum/Rotor Size:	mm	mm
Lining Size:	mm	mm
Lining Codes:	DM121 EE	241 FG
Lining Attachment:	Bonded	Riveted
Wheel Cyl/Piston dia:		

Weights - Curb Weight - Frt: 1082 kg Rear: 774 kg Total: 1856 kg

Test Weight LLVW - Frt: 1206 kg Rear: 803 kg Total: 2009 kg

Test Weight GVW - Frt: 1177 kg Rear: 1381 kg Total: 2558 kg

Center of Gravity -

Height Above Ground - Curb: 734 mm LLVW: 763 mm GVW: 745 mm

Aft of Front Axle - Curb: 1398 mm LLVW: 1340 mm GVW: 1810 mm

Moments of Inertia (ft-lb/sec^2)	CURB	LLVW	GVW
Roll (About X Axis):	538.1	479.4	NA
Pitch (About Y Axis):	3430.0	3540.4	NA
Yaw (About Z Axis):	3908.2	4307.4	NA

Vehicle Maximum Speed: 161 km/h

Comments: Rear Axle Antilock System

Summary of Performance to Modified Harmonized Brake Test Procedure

Vehicle Chevrolet C-1500 Tested by VRTC

Date Test Completed 11/4/87 80% V_{max} = 129 km/h

Service Brake and Partial Failure Tests (Results for "best" stops)

	Laden				Unladen			
	100 km/h in neutral		80% V_{max} in gear		100 km/h in neutral		80% V_{max} in gear	
	SD (m)	PF_{max} (N)	SD (m)	PF_{max} (N)	SD (m)	PF_{max} (N)	SD (m)	PF_{max} (N)
Full Service Braking								
Engine On:	64	449	101	480	55	405	88	480
Engine Off:	54	471	NA	NA	NA	NA	NA	NA
Post Fade:	62	462	NA	NA	NA	NA	NA	NA
Partial Failures (Engine On):								
Circuit #1 Failed:	84	462	NA	NA	72	414	NA	NA
Circuit #2 Failed:	142	498	NA	NA	135	409	NA	NA
Anti-lock Failed:	60	498	NA	NA	55	445	NA	NA
Variable Prop. Valve Failed:	NA	NA	NA	NA	NA	NA	NA	NA
Power Unit/Assist Failed:	120	498	NA	NA	NA	NA	NA	NA

Adhesion Utilization

Low Coefficient Effectiveness

	SD (m)	PF_{max} (N)
Laden	27	276
Unladen	23	298

Axle Lock Sequence

	Balanced	Front	Rear
20 SN:			
Laden		X	
Unladen		X	
50 SN:			
Laden		X	
Unladen		X	

Parking Brake Tests

20% Grade

Control Force to Hold:

Uphill 445 N

Downhill 467 N

Dynamic Test

Results for Best Stop:

SD 59 m

Final Decel 2.74 m/s^2

PF_{max} 409 N

Fade and Recovery Series

Baseline: Best Stop SD 64 m Avg PF 311 N

Heating: Stops 1-15 PF_{max} 160 N

Stops 1-15 Min Decel Sus 2.90 m/s^2

Stop 15 Initial Temp (C)

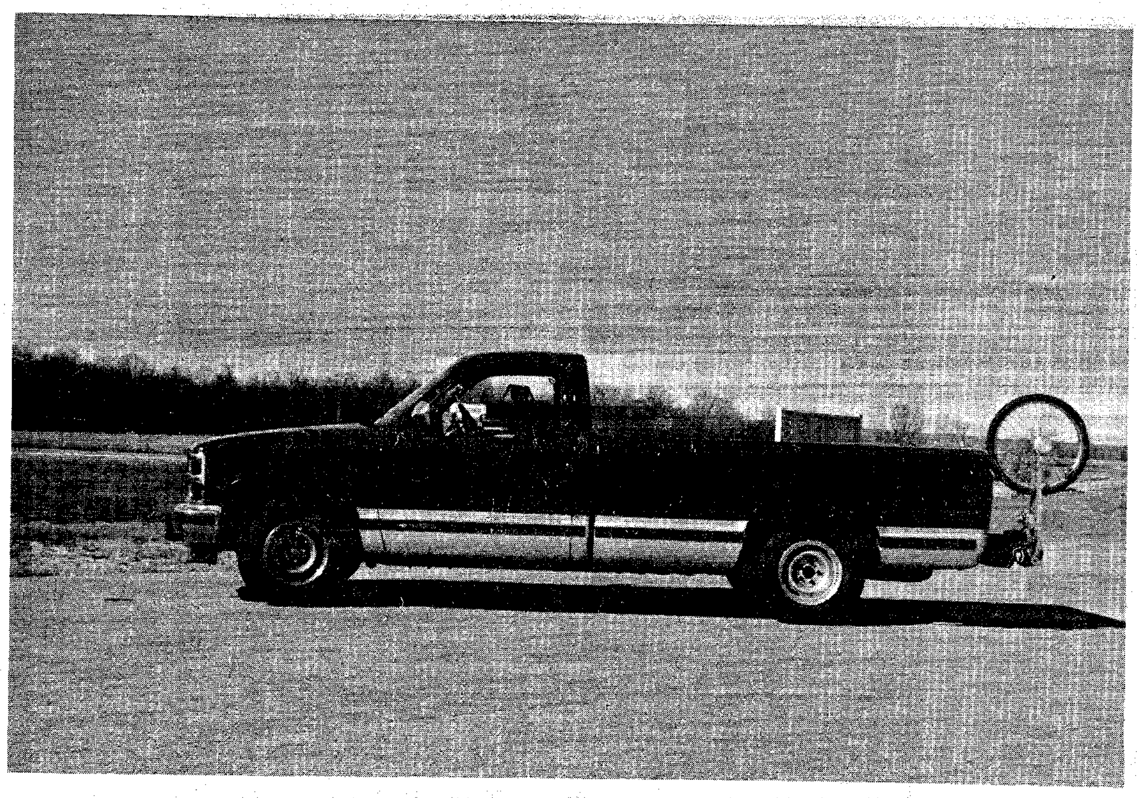
LF 432 RF 466 LR 210 RR 199

Hot Stop: SD 91 m PF_{max} 311 N

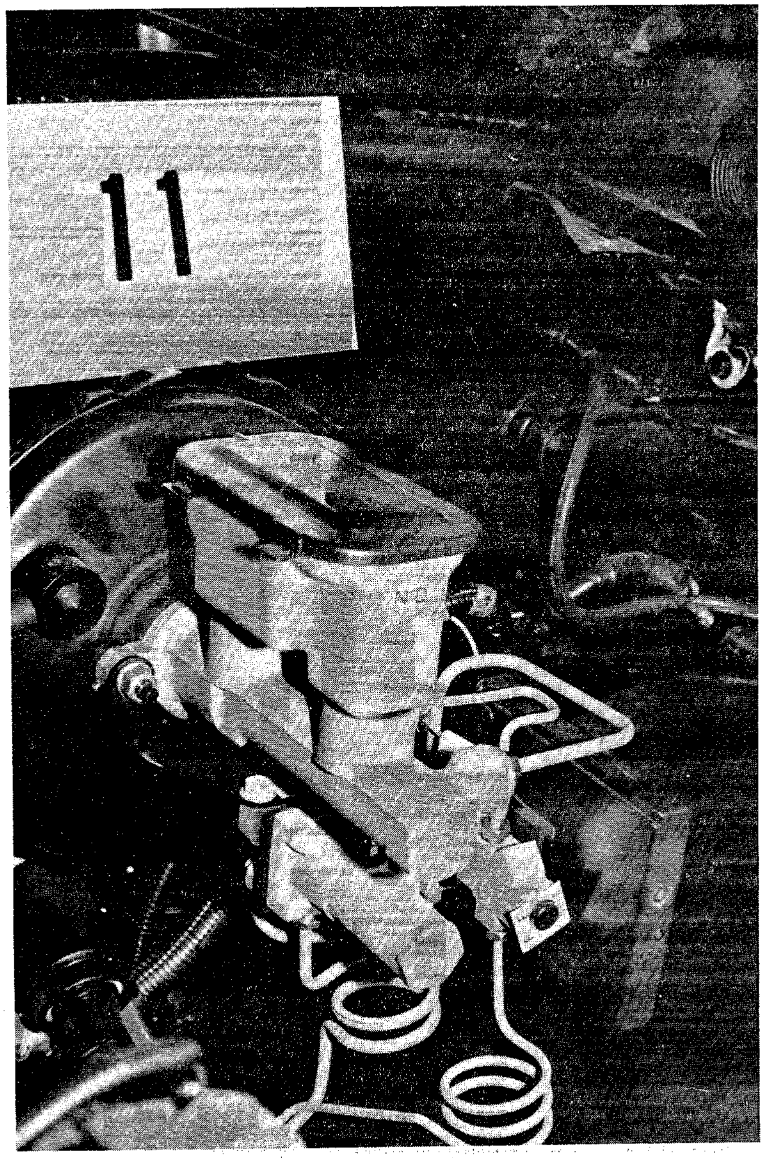
Recovery: Stops 1-4 PF_{max} 147 N

Recovery Stop: SD 77 m PF_{max} 311 N

(Rev. 2/6/87)



1988 Chevrolet C-1500



Chevrolet C-1500 Master Cylinder and Antilock Valve

Test Vehicle Information/Specifications

Vehicle Type: Pickup Wheelbase: 3391 mm

Manufacturer: Ford Model: F-150 4x4

VIN: F14FLHD6690 Production Date: 1/80

GVWR: 2631 kg GAWR - Frt: 1281 kg Rear: 1460 kg

Engine-Type: Gas No. Cyl: ______ Disp: 1

Transmission-Type: Standard Fwd Spds: 4 Drive Axle: Rear

Tires-Mfgr: Atlas Style: Radial

Size: 235/75 R15 Test Press - Frt: 2.4 bar Rear: 2.4 bar

Grade	LF	RF	LR	RR
Treadwear:	NA	NA	NA	NA
Traction:	NA	NA	NA	NA
Temperature:	NA	NA	NA	NA
Serial Number:	NA	NA	NA	NA
Estimated Mileage:	1000	1000	1000	1000

Brake System - Booster-Type: Vacuum

Parking Brake-Type: Rear Shoes Control: Foot

Prop. Valve-Type: Fixed Split Point: 283 Ratio: 0.46

Plumbing Split Type: Front/Rear

	Front	Rear
Brake Type:	Disc	Drum
Drum/Rotor Size:	mm	mm
Lining Size:	mm	mm
Lining Codes:		
Lining Attachment:		
Wheel Cyl/Piston dia:		

Weights - Curb Weight - Frt: 1004 kg Rear: 1000 kg Total: 2004 kg

Test Weight LLVW - Frt: 1184 kg Rear: 948 kg Total: 2132 kg

Test Weight GVW - Frt: 1227 kg Rear: 1411 kg Total: 2638 kg

Center of Gravity -

Height Above Ground - Curb: 706 mm LLVW: 737 mm GVW: 794 mm

Aft of Front Axle - Curb: 1692 mm LLVW: 1508 mm GVW: 1814 mm

Moments of Inertia (ft-lb/sec^2)	CURB	LLVW	GVW
Roll (About X Axis):	NA	NA	NA
Pitch (About Y Axis):	NA	NA	NA
Yaw (About Z Axis):	NA	NA	NA

Vehicle Maximum Speed: 145 km/h

Comments:

Summary of Performance to Modified Harmonized Brake Test Procedure

Vehicle Ford F-150 4x4 Tested by VRTC

Date Test Completed 11/18/87 80% V_{max} = 116 km/h

Service Brake and Partial Failure Tests (Results for "best" stops)

	Laden				Unladen			
	100 km/h in neutral		80% V_{max} in gear		100 km/h in neutral		80% V_{max} in gear	
Full Service Braking	SD (m)	PF_{max} (N)	SD (m)	PF_{max} (N)	SD (m)	PF_{max} (N)	SD (m)	PF_{max} (N)
Engine On:	58	356	77	409	56	329	70	365
Engine Off:	56	391	NA	NA	NA	NA	NA	NA
Post Fade:	66	347	NA	NA	NA	NA	NA	NA
Partial Failures (Engine On):								
Circuit #1 Failed:	83	391	NA	NA	74	409	NA	NA
Circuit #2 Failed:	123	498	NA	NA	125	249	NA	NA
Anti-lock Failed:	NA	NA	NA	NA	NA	NA	NA	NA
Variable Prop. Valve Failed:	NA	NA	NA	NA	NA	NA	NA	NA
Power Unit/Assist Failed:	129	498	NA	NA	NA	NA	NA	NA

Adhesion Utilization

Low Coefficient Effectiveness

	SD (m)	PF_{max} (N)
Laden	27	160
Unladen	24	160

Axle Lock Sequence

	Balanced	Front	Rear
20 SN:			
Laden		X	
Unladen		X	
50 SN:			
Laden		X	
Unladen		X	

Parking Brake Tests

20% Grade

Control Force to Hold:

Uphill 667 N

Downhill 632 N

Dynamic Test

Results for Best Stop:

SD 119 m

Final Decel 1.52 m/s^2

PF_{max} 498 N

Fade and Recovery Series

Baseline: Best Stop SD 58 m Avg PF 231 N

Heating: Stops 1-15 PF_{max} 182 N

Stops 1-15 Min Decel Sus 2.90 m/s^2

Stop 15 Initial Temp (C)

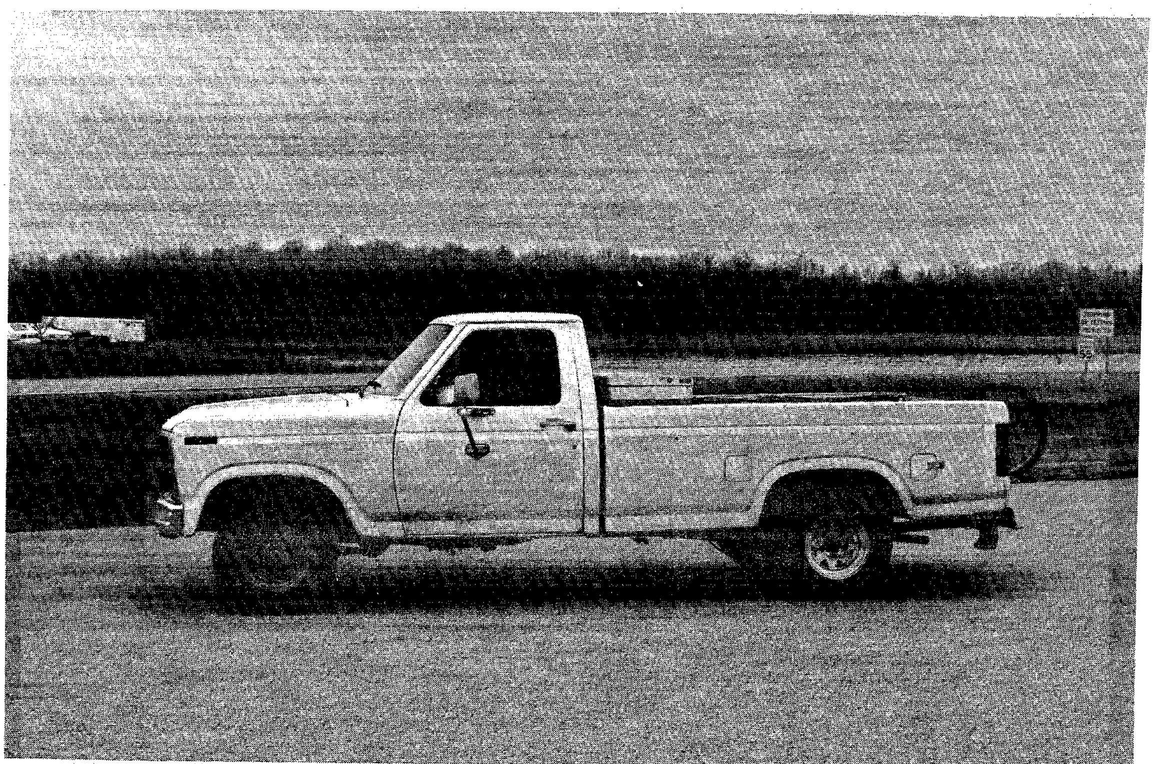
LF 340 RF 382 LR 166 RR 160

Hot Stop: SD 70 m PF_{max} 222 N

Recovery: Stops 1-4 PF_{max} 151 N

Recovery Stop: SD 74 m PF_{max} 227 N

(Rev. 2/6/87)



1980 Ford F-150 4x4

Test Vehicle Information/Specifications

Vehicle Type: Pickup — Wheelbase: 2845 mm

Manufacturer: Dodge — Model: Dakota

VIN: 1B7FN14C8HS327073 — Production Date: 9/86

GVWR: 1865 kg GAWR - Frt: 1089 kg Rear: 1044 kg

Engine-Type: Gas — No. Cyl: 4 — Disp: 2.2 l

Transmission-Type: Standard — Fwd Spds: 5 — Drive Axle: Rear

Tires-Mfgr: Goodyear — Style: Vector Radial

Size: P195/75R14 — Test Press - Frt: ____ bar Rear: ____ bar

Grade	LF	RF	LR	RR
Treadwear:	280	280	280	280
Traction:	A	A	A	A
Temperature:	B	B	B	B
Serial Number:	261257-GCW-34C	261258-GCW-34C	261262-GCW-34C	261259-GCW-34C
Estimated Mileage:	600	600	600	600

Brake System -

Booster-Type: Vacuum

Parking Brake-Type: Shoes of rear brake — Control: Foot

Prop. Valve-Type: Height Sensing — Split Point: ____ — Ratio: 0.252

Plumbing Split Type: Front/Rear

	Front	Rear
Brake Type:	Disc	Drum
Drum/Rotor Size:	mm	mm
Lining Size:	mm	mm
Lining Codes:	BX JD EE	BX-RY-FE / BX-PM-FE
Lining Attachment:		
Wheel Cyl/Piston dia:		

Weights	Frt	Rear	Total
Curb Weight	712 kg	562 kg	1274 kg
Test Weight LLVW	812 kg	712 kg	1524 kg
Test Weight GVW	925 kg	939 kg	1964 kg

Center of Gravity -

	Curb	LLVW	GVW
Height Above Ground	600 mm	617 mm	625 mm
Aft of Front Axle	1255 mm	1329 mm	1360 mm

Moments of Inertia (ft-lb/sec^2)	CURB	LLVW	GVW
Roll (About X Axis):	376.8	460.5	590.5
Pitch (About Y Axis):	1831.3	2130.5	2298.3
Yaw (About Z Axis):	1986.5	2194.3	2596.5

Vehicle Maximum Speed: 140 km/h

Comments:

Summary of Performance to Modified Harmonized Brake Test Procedure

Vehicle Dodge Dakota   Tested by VRTC

Date Test Completed 7/8/87   80% V_{max} = 112 km/h

Service Brake and Partial Failure Tests (Results for "best" stops)

	Laden				Unladen			
	100 km/h in neutral		80% V_{max} in gear		100 km/h in neutral		80% V_{max} in gear	
Full Service Braking	SD (m)	PF_{max} (N)	SD (m)	PF_{max} (N)	SD (m)	PF_{max} (N)	SD (m)	PF_{max} (N)
Engine On:	53	436	64	445	57	418	66	445
Engine Off:	52	400	NA	NA	NA	NA	NA	NA
Post Fade:	60	311	NA	NA	NA	NA	NA	NA
Partial Failures (Engine On):								
Circuit #1 Failed:	74	409	NA	NA	69	374	NA	NA
Circuit #2 Failed:	122	285	NA	NA	130	178	NA	NA
Anti-lock Failed:	NA	NA	NA	NA	NA	NA	NA	NA
Variable Prop. Valve Failed:	63	342	NA	NA	58	391	NA	NA
Power Unit/Assist Failed:	132	498	NA	NA	NA	NA	NA	NA

Adhesion Utilization

Low Coefficient Effectiveness

	SD (m)	PF_{max} (N)
Laden	24	160
Unladen	25	129

Axle Lock Sequence

	Balanced	Front	Rear
20 SN:			
Laden		X	
Unladen		X	
50 SN:			
Laden		X	
Unladen		X	

Parking Brake Tests

20% Grade

Control Force to Hold:

Uphill 262 N

Downhill 231 N

Dynamic Test

Results for Best Stop:

SD 44 m

Final Decel 3.81 m/s^2

PF_{max} 285 N

Fade and Recovery Series

Baseline: Best Stop SD 53 m Avg PF 231 N

Heating: Stops 1-15 PF_{max} 116 N

Stops 1-15 Min Decel Sus 3.05 m/s^2

Stop 15 Initial Temp (C)

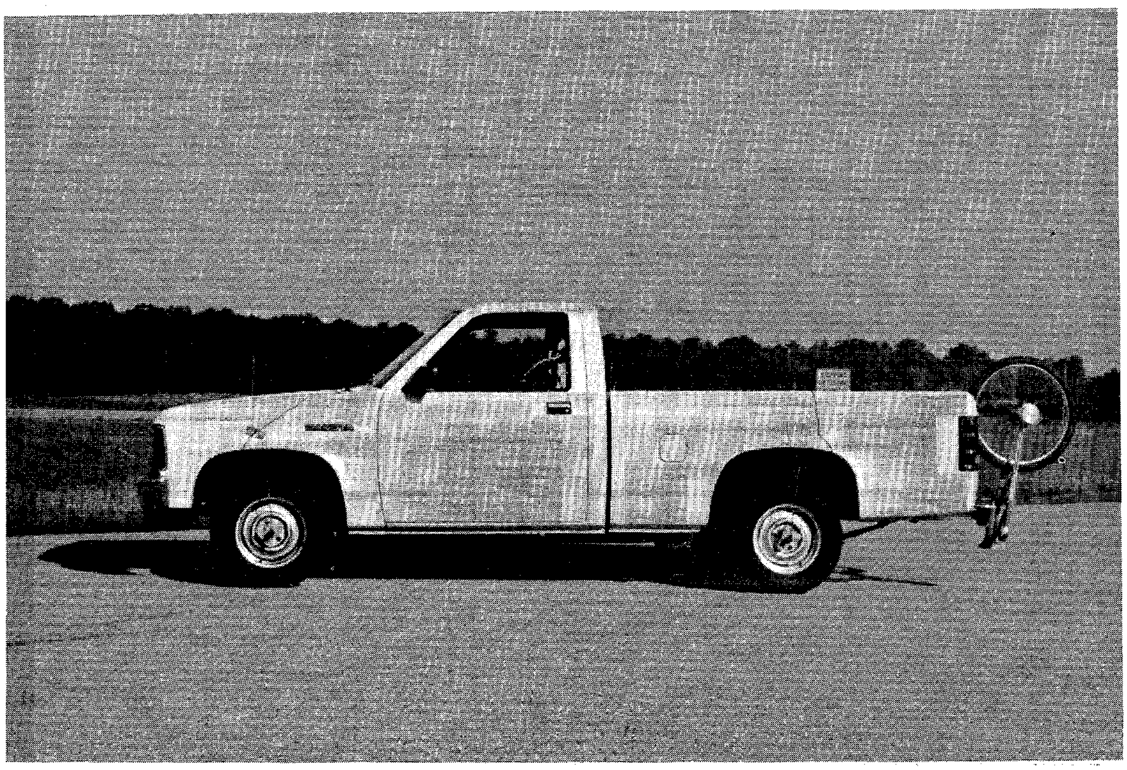
LF 349 RF 379 LR 149 RR 129

Hot Stop: SD 71 m PF_{max} 227 N

Recovery: Stops 1-4 PF_{max} 89 N

Recovery Stop: SD 64 m PF_{max} 231 N

(Rev. 2/6/87)



1987 Dodge Dakota

Test Vehicle Information/Specifications

Vehicle Type: Multipurpose   Wheelbase: 2625 mm

Manufacturer: Toyota   Model: 4-Runner

VIN: JT4RN62S5H0140017   Production Date: 2/87

GVWR: 2304 kg GAWR - Frt: 1100 kg Rear: 1361 kg

Engine-Type: Gas   No. Cyl: 4   Disp: 2.4 l

Transmission-Type: Manual   Fwd Spds: 5   Drive Axle:

Tires-Mfgr: Bridgestone   Style: Desert Dueler Radial

Size: P225/75 R15   Test Press - Frt: ____ bar Rear: ____ bar

Grade	LF	RF	LR	RR
Treadwear:	180	180	180	180
Traction:	B	B	B	B
Temperature:	B	B	B	B
Serial Number:	T8401	T8402	T8402	T8403
Estimated Mileage:	4000	4000	4000	4000

Brake System - Booster-Type: Vacuum

Parking Brake-Type: Rear Brake   Control: Hand

Prop. Valve-Type: Height Sensing Split Point: Variable Ratio: 0.25

Plumbing Split Type: Front/Rear

	Front	Rear
Brake Type:	Disc	Drum
Drum/Rotor Size:	287 mm	295 mm
Lining Size:	125.7x52.5x97 mm	296x50x6 mm
Lining Codes:	M2207FG	M2207FG
Lining Attachment:	Bonded	Bonded
Wheel Cyl/Piston dia:	42.85 + 33.96	22.22

Weights - Curb Weight - Frt: 852 kg Rear: 740 kg Total: 1592 kg

Test Weight LLVW - Frt: 948 kg Rear: 803 kg Total: 1751 kg

Test Weight GVW - Frt: 1030 kg Rear: 1275 kg Total: 2305 kg

Center of Gravity -

Height Above Ground - Curb: 737 mm LLVW: 766 mm GVW: 805 mm

Aft of Front Axle - Curb: 1220 mm LLVW: 1204 mm GVW: 1452 mm

Moments of Inertia (ft-lb/sec^2)	CURB	LLVW	GVW
Roll (About X Axis):	242.1	532.4	528.2
Pitch (About Y Axis):	1793.2	2257.5	2593.2
Yaw (About Z Axis):	2692.4	2404.1	2890.6

Vehicle Maximum Speed: 148 km/h

Comments:

Summary of Performance to Modified Harmonized Brake Test Procedure

Vehicle Toyota 4-Runner   Tested by VRTC

Date Test Completed 9-2-87   80% V_{max} = 118 km/h

Service Brake and Partial Failure Tests (Results for "best" stops)

	Laden				Unladen			
	100 km/h in neutral		80% V_{max} in gear		100 km/h in neutral		80% V_{max} in gear	
	SD (m)	PF_{max} (N)	SD (m)	PF_{max} (N)	SD (m)	PF_{max} (N)	SD (m)	PF_{max} (N)
Full Service Braking								
Engine On:	60	480	83	489	52	400	73	418
Engine Off:	63	409	NA	NA	NA	NA	NA	NA
Post Fade:	61	485	NA	NA	NA	NA	NA	NA
Partial Failures (Engine On):								
Circuit #1 Failed:	164	498	NA	NA	146	498	NA	NA
Circuit #2 Failed:	75	480	NA	NA	69	320	NA	NA
Anti-lock Failed:	NA	NA	NA	NA	NA	NA	NA	NA
Variable Prop. Valve Failed:	63	436	NA	NA	55	240	NA	NA
Power Unit/Assist Failed:	100	498	NA	NA	NA	NA	NA	NA

Adhesion Utilization

Low Coefficient Effectiveness

	SD (m)	PF_{max} (N)
Laden	25	187
Unladen	22	196

Axle Lock Sequence

	Balanced	Front	Rear
20 SN:			
Laden		X	
Unladen		X	
50 SN:			
Laden		X	
Unladen		X	

Parking Brake Tests

20% Grade

Control Force to Hold:

Uphill 298 N

Downhill 289 N

Dynamic Test

Results for Best Stop:

SD 113 m

Final Decel 1.83 m/s^2

PF_{max} 391 N

Fade and Recovery Series

Baseline: Best Stop SD 60 m Avg PF 391 N

Heating: Stops 1-15 PF_{max} 187 N

Stops 1-15 Min Decel Sus 3.05 m/s^2

Stop 15 Initial Temp (C)

LF 349 RF 338 LR 199 RR 232

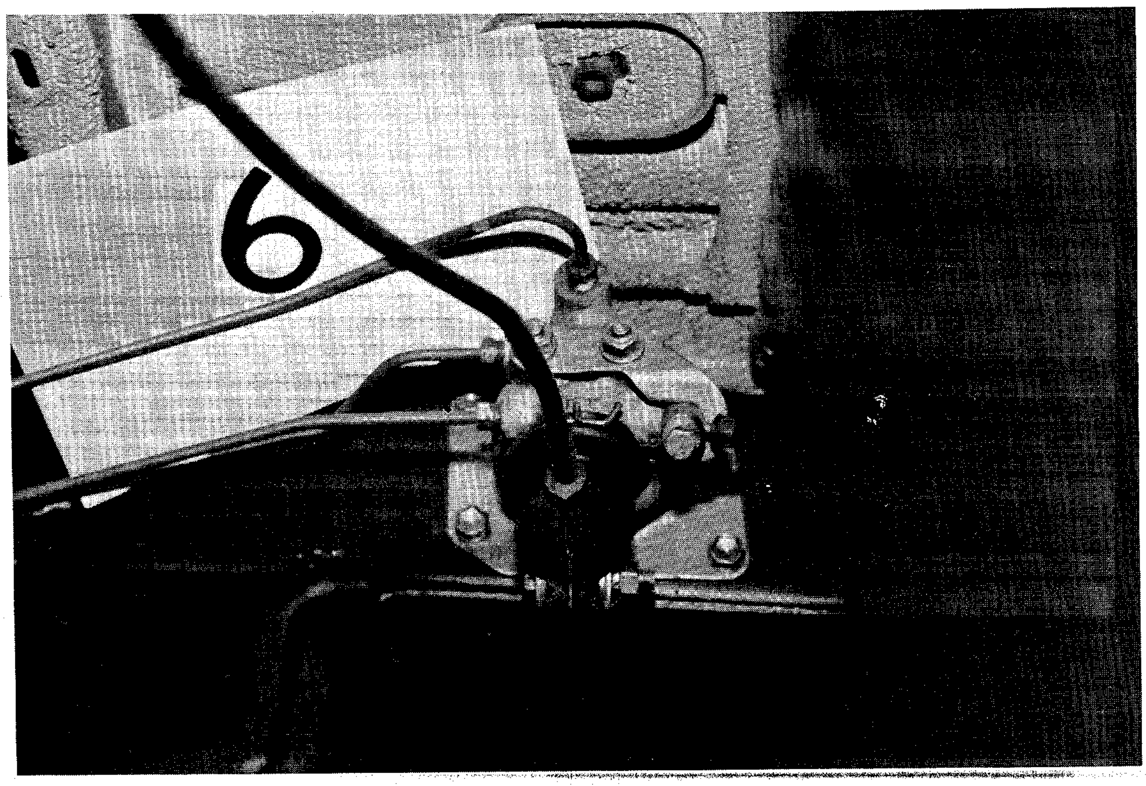
Hot Stop: SD 69 m PF_{max} 382 N

Recovery: Stops 1-4 PF_{max} 124 N

Recovery Stop: SD 68 m PF_{max} 320 N

(Rev. 2/6/87)

1987 Toyota 4-Runner



Toyota 4-Runner Height Sensing Proportioning Valve

Test Vehicle Information/Specifications

Vehicle Type: MPV Wheelbase: 2576 mm

Manufacturer: AMC Model: Cherokee

VIN: 1JCMR7824HT091269 Production Date: 1/87

GVWR: 1960 kg GAWR - Frt: 1134 kg Rear: 1225 kg

Engine-Type: Gas No. Cyl: 6 Disp: 4.0 l

Transmission-Type: Automatic Fwd Spds: 4 Drive Axle: Rear

Tires-Mfgr: Goodyear Style: Radial

Size: P205/75 R15 Test Press - Frt: 2.4 bar Rear: 2.4 bar

Grade	LF	RF	LR	RR
Treadwear:	280	280	280	280
Traction:	A	A	A	A
Temperature:	B	B	B	B
Serial Number:	M6ULBA1376	M6ULBA1146	M6ULBA1386	M6ULBA1146
Estimated Mileage:	4000	4000	4000	4000

Brake System - Booster-Type: Vacuum

Parking Brake-Type: Rear Brake Control: Hand

Prop. Valve-Type: Fixed Prop Split Point: 229 Ratio: 0.260

Plumbing Split Type: Front/Rear

	Front	Rear
Brake Type:	Disc	Drum
Drum/Rotor Size:	280x22 mm	254 mm
Lining Size:	mm	mm
Lining Codes:	BX-XO-EE	BX-RM-EE / BX-RW-EE
Lining Attachment:	Rivet	Rivet
Wheel Cyl/Piston dia:		

Weights - Curb Weight - Frt: 880 kg Rear: 644 kg Total: 1524 kg

Test Weight LLVW - Frt: 973 kg Rear: 735 kg Total: 1708 kg

Test Weight GVW - Frt: 996 kg Rear: 1064 kg Total: 2059 kg

Center of Gravity -

Height Above Ground - Curb: 693 mm LLVW: 710 mm GVW: 700 mm

Aft of Front Axle - Curb: 1088 mm LLVW: 1108 mm GVW: 1331 mm

Moments of Inertia (ft-lb/sec^2)	CURB	LLVW	GVW
Roll (About X Axis):	460.1	259.6	518.7
Pitch (About Y Axis):	1920.8	1891.3	2247.6
Yaw (About Z Axis):	2045.2	2170.0	2714.4

Vehicle Maximum Speed: 168 km/h

Comments: 4-Wheel Drive

Summary of Performance to Modified Harmonized Brake Test Procedure

Vehicle: Jeep Cherokee   Tested by: VRTC

Date Test Completed: 7/17/87   80% V_{max} = 134 km/h

Service Brake and Partial Failure Tests (Results for "best" stops)

	Laden				Unladen			
	100 km/h in neutral		80% V_{max} in gear		100 km/h in neutral		80% V_{max} in gear	
	SD (m)	PF_{max} (N)	SD (m)	PF_{max} (N)	SD (m)	PF_{max} (N)	SD (m)	PF_{max} (N)
Full Service Braking								
Engine On:	66	480	108	480	58	400	95	445
Engine Off:	66	427	NA	NA	NA	NA	NA	NA
Post Fade:	65	338	NA	NA	NA	NA	NA	NA
Partial Failures (Engine On):								
Circuit #1 Failed:	79	356	NA	NA	71	258	NA	NA
Circuit #2 Failed:	126	480	NA	NA	153	245	NA	NA
Anti-lock Failed:	NA	NA	NA	NA	NA	NA	NA	NA
Variable Prop. Valve Failed:	NA	NA	NA	NA	NA	NA	NA	NA
Power Unit/Assist Failed:	116	498	NA	NA	NA	NA	NA	NA

Adhesion Utilization

Low Coefficient Effectiveness

	SD (m)	PF_{max} (N)
Laden	27	222
Unladen	24	196

Axle Lock Sequence

	Balanced	Front	Rear
20 SN:			
Laden		X	
Unladen		X	
50 SN:			
Laden		X	
Unladen		X	

Parking Brake Tests

20% Grade

Control Force to Hold:

Uphill 311 N

Downhill 222 N

Dynamic Test

Results for Best Stop:

SD 63 m

Final Decel 3.35 m/s^2

PF_{max} 258 N

Fade and Recovery Series

Baseline: Best Stop SD 66 m Avg PF 356 N

Heating: Stops 1-15 PF_{max} 133 N

Stops 1-15 Min Decel Sus 3.05 m/s^2

Stop 15 Initial Temp (C)

LF 429 RF 427 LR 149 RR 118

Hot Stop: SD 85 m PF_{max} 347 N

Recovery: Stops 1-4 PF_{max} 107 N

Recovery Stop: SD 69 m PF_{max} 356 N

(Rev. 2/6/87)

1987 AMC Cherokee

APPENDIX C

Tabular Results -- FMVSS 135 Notice 4 Tests

Low Coefficient Test Results

Vehicle	Laden 50 km/h SD (m)	Laden PFmax (N)	Laden Axle Lock 20 SN	Laden Axle Lock 50 SN	Unladen 50 km/h SD (m)	Unladen PFmax (N)	Unladen Axle Lock 20 SN	Unladen Axle Lock 50 SN
Dodge Caravan	26	196	Front	Front	25	214	Front	Front
Toyota Van	28	151	Front	Front	24	173	Front	Front
Chevrolet Astro	29	222	Front	Front	22	285	Front	Front
Ford E-250	29	214	Front	Rear	27	138	Front	Front
Nissan Truck	25	156	Front	Front	26	116	Front	Front
Chevrolet S-10	35	116	Front	Front	26	124	Front	Front
Ford Ranger	30	111	Front	Rear	24	102	Front	Rear
Ford F-150	36	93	Front	Front	32	93	Front	Front
Chevrolet C-1500	27	276	Front	Front	23	298	Front	Front
Ford F-150 4X4	27	160	Front	Front	24	160	Front	Front
Dodge Dakota	24	160	Front	Front	25	129	Front	Front
Toyota 4-Runner	25	187	Front	Front	22	196	Front	Front
Jeep Cherokee	27	222	Front	Front	24	196	Front	Front
Average	28.3				24.9			

Laden Full System Results

Vehicle	80 % Vmax (km/h)	Engine On 100 km/h SD (m)	Engine On 100 km/h PFmax (N)	Engine On 80% Vmax SD (m)	Engine On 80% Vmax PFmax (N)	Engine Off 100 km/h SD (m)	Engine Off 100 km/h PFmax (N)	Post Fade 100 km/h SD (m)	Post Fade 100 km/h PFmax (N)
Dodge Caravan	113	61	427	78	498	58	485	57	489
Toyota Van	108	64	427	72	445	57	445	59	467
Chevrolet Astro	130	54	462	92	492	59	445	59	374
Ford E-250	126	59	445	93	445	58	374	59	445
Nissan Truck	120	65	462	97	356	69	445	65	294
Chevrolet S-10	121	61	498	88	498	62	498	60	498
Ford Ranger	116	50	196	68	249	46	298	47	267
Ford F-150	135	58	258	96	280	58	236	56	245
Chevrolet C-1500	129	64	449	101	480	54	471	62	462
Ford F-150 4X4	116	58	356	77	409	56	391	66	347
Dodge Dakota	112	53	436	64	445	52	400	60	311
Toyota 4-Runner	118	60	480	83	489	63	409	61	485
Jeep Cherokee	134	66	480	108	480	66	427	65	338
Average		59.5				58.3		59.7	

Unladen Full System Results

Vehicle	80 % Vmax (km/h)	100 km/h SD (m)	100 km/h PFmax (N)	80% Vmax SD (m)	80% Vmax PFmax (N)
Dodge Caravan	113	51	445	67	400
Toyota Van	108	54	276	63	334
Chevrolet Astro	130	51	498	82	498
Ford E-250	126	55	436	91	427
Nissan Truck	120	57	436	80	400
Chevrolet S-10	121	54	436	77	374
Ford Ranger	116	60	124	69	124
Ford F-150	135	52	320	94	302
Chevrolet C-1500	129	55	405	88	480
Ford F-150 4X4	116	56	329	70	365
Dodge Dakota	112	57	418	66	445
Toyota 4-Runner	118	52	400	73	418
Jeep Cherokee	134	58	400	95	445
Average		54.8			

Laden Failed System Results

Vehicle	Circuit #1 SD (m)	Circuit #1 PFmax (N)	Circuit #2 SD (m)	Circuit #2 PFmax (N)	A.L./V.P. SD (m)	A.L./V.P. PFmax (N)	Power Assist SD (m)	Power Assist PFmax (N)
Dodge Caravan	113	480	114	485	63	NA	161	494
Toyota Van	146	498	70	480	57	498	135	498
Chevrolet Astro	72	445	135	498			144	498
Ford E-250	129	480	81	436	63	445	144	498
Nissan Truck	88	334	118	480	52	436	131	494
Chevrolet S-10	80	445	182	498			180	498
Ford Ranger	78	267	104	489			62	498
Ford F-150	198	489	75	231	57	316	73	498
Chevrolet C-1500	84	462	142	498	60	498	120	498
Ford F-150 4X4	83	391	123	498			129	498
Dodge Dakota	74	409	122	285	63	342	132	498
Toyota 4-Runner	164	498	75	480	63	436	100	498
Jeep Cherokee	79	356	126	480			116	498
Average	106.7		112.8				125.1	
Overall Average		109.8						

Unladen Failed System Results

Vehicle	Circuit #1 SD (m)	Circuit #1 PFmax (N)	Circuit #2 SD (m)	Circuit #2 PFmax (N)	A.L./V.P. SD (m)	A.L./V.P. PFmax (N)
Dodge Caravan	108	454	122	325	61	NA
Toyota Van	156	187	59	316	58	280
Chevrolet Astro	62	480	139	485		
Ford E-250	144	498	73	360	55	480
Nissan Truck	76	240	127	249	67	142
Chevrolet S-10	67	400	161	480		
Ford Ranger	68	214	124	214		
Ford F-150	201	480	64	262	53	262
Chevrolet C-1500	72	414	135	409	55	445
Ford F-150 4X4	74	409	125	249		
Dodge Dakota	69	374	130	178	58	391
Toyota 4-Runner	146	498	69	320	55	240
Jeep Cherokee	71	258	153	245		
Average	101.0		113.9			
Overall Average		107.5				

Fade and Recovery Results

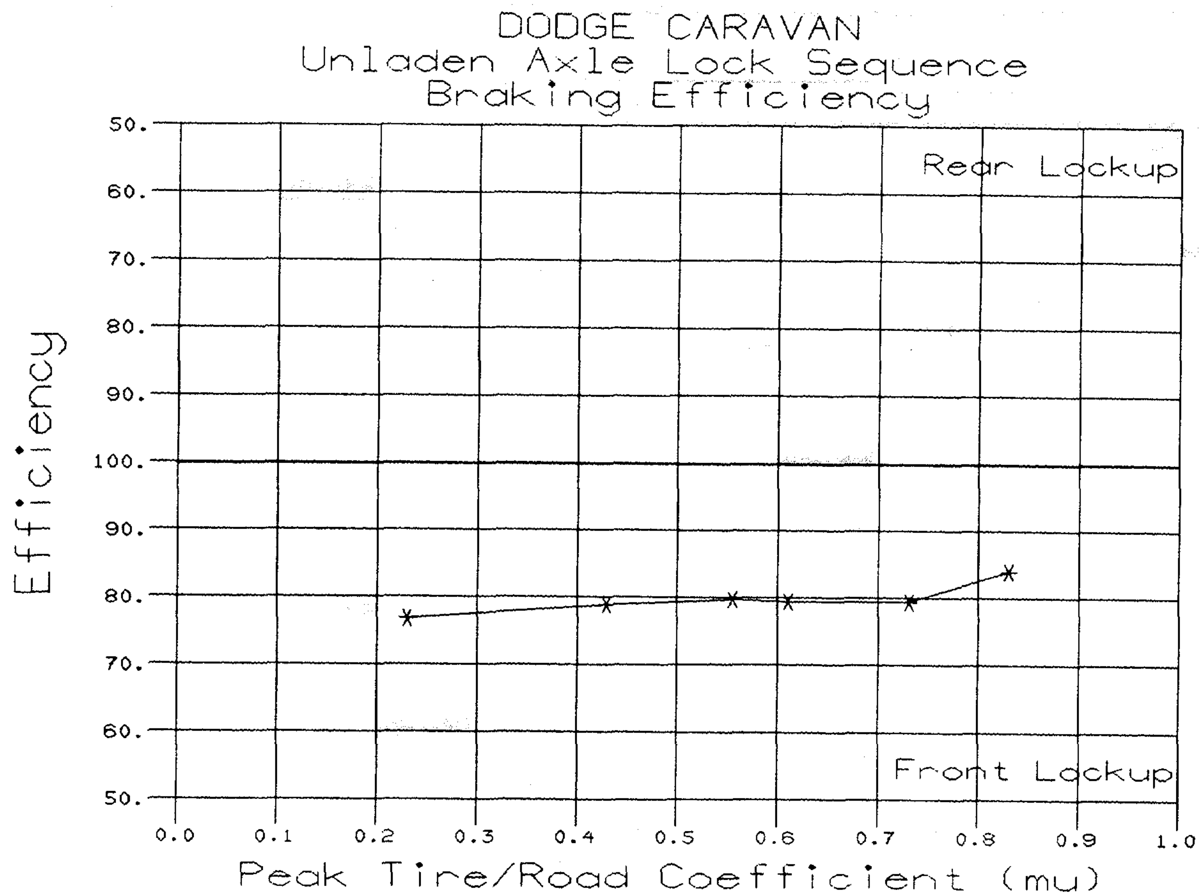
Vehicle	Snub 15 IBT Front (C)	Snub 15 IBT Rear (C)	Hot Stop SD (m)	Hot Stop PFmax (N)	Recover Stop SD (m)	Recover Stop PFmax (N)
Dodge Caravan	418	142	80	249	66	249
Toyota Van	432	193	73	245	66	231
Chevrolet Astro	377	185	61	378	56	391
Ford E-250	478	140	104	271	71	267
Nissan Truck	506	234	72	258	68	258
Chevrolet S-10	505	160	75	454	65	462
Ford Ranger	322	168	73	129	61	129
Ford F-150	377	206	81	147	66	142
Chevrolet C-1500	449	205	91	311	77	311
Ford F-150 4X4	361	163	70	222	74	227
Dodge Dakota	364	139	71	227	64	231
Toyota 4-Runner	344	215	69	382	68	320
Jeep Cherokee	428	134	85	347	69	356
Average			77.3		67.0	

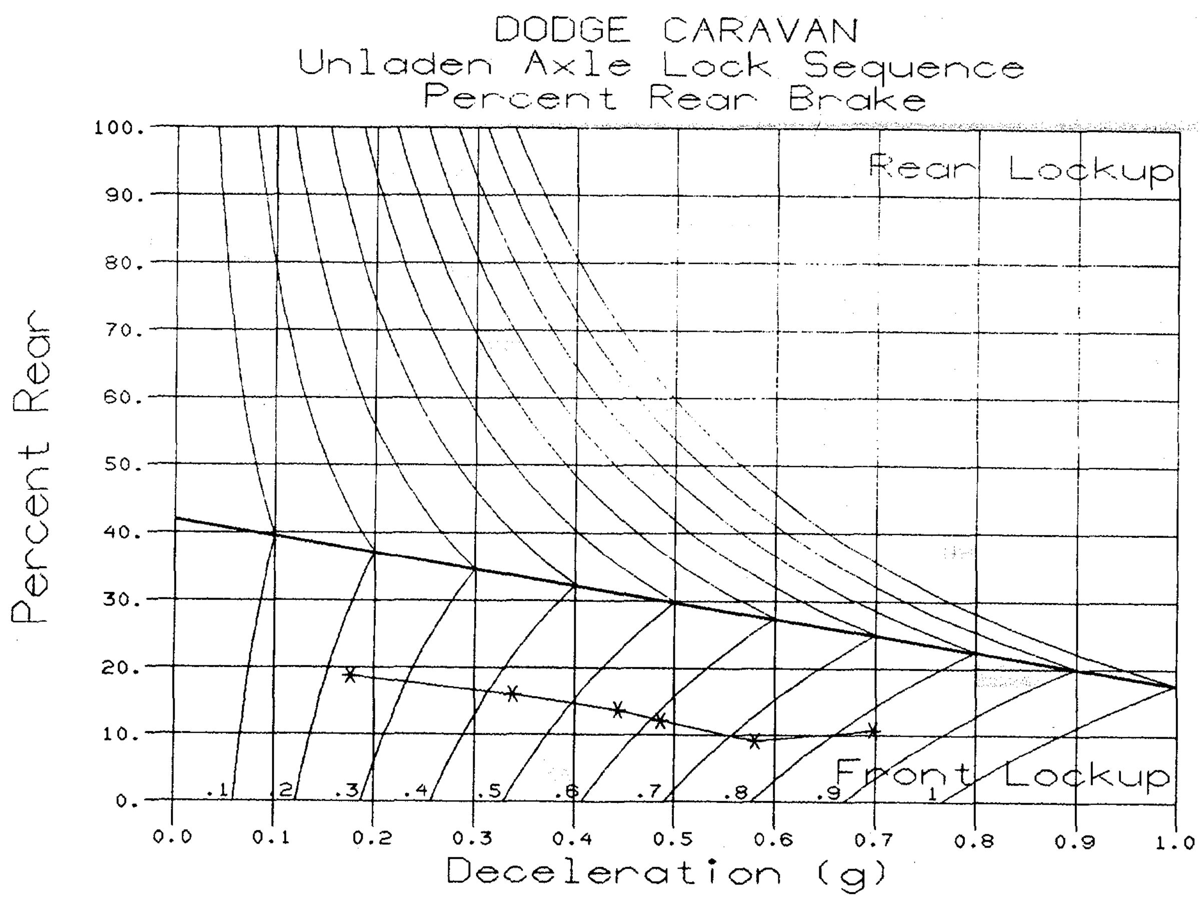
Parking Brake Results

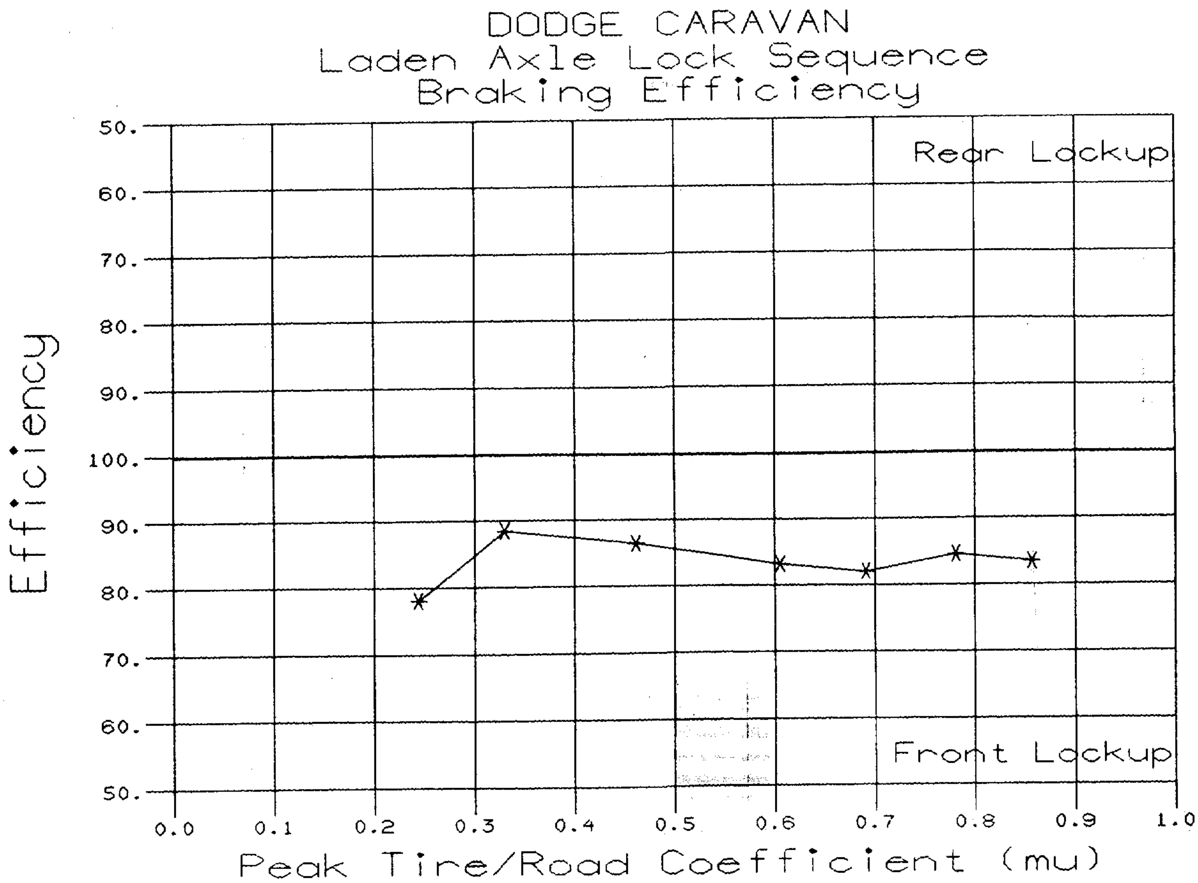
Vehicle	Static 20 % Grade Minimum Force Up (N)	Static 20 % Grade Minimum Force Down (N)	60 km/h Stops SD (m)	60 km/h Stops Final Decel (m/s/s)	60 km/h Stops PFmax (N)
Dodge Caravan	365	311	72	3.96	391
Toyota Van	254	222	58	2.74	391
Chevrolet Astro	462	445	50	3.05	498
Ford E-250	462	427	43	3.96	445
Nissan Truck	222	222	54	3.05	400
Chevrolet S-10	391	311	66	3.05	498
Ford Ranger	285	218	49	3.96	302
Ford F-150	498	485	76	1.98	498
Chevrolet C-1500	445	467	59	2.74	409
Ford F-150 4X4	667	632	119	1.52	498
Dodge Dakota	262	231	44	3.81	285
Toyota 4-Runner	298	289	113	1.83	391
Jeep Cherokee	311	222	63	3.35	258
Average	379	345	66.6	3.00	

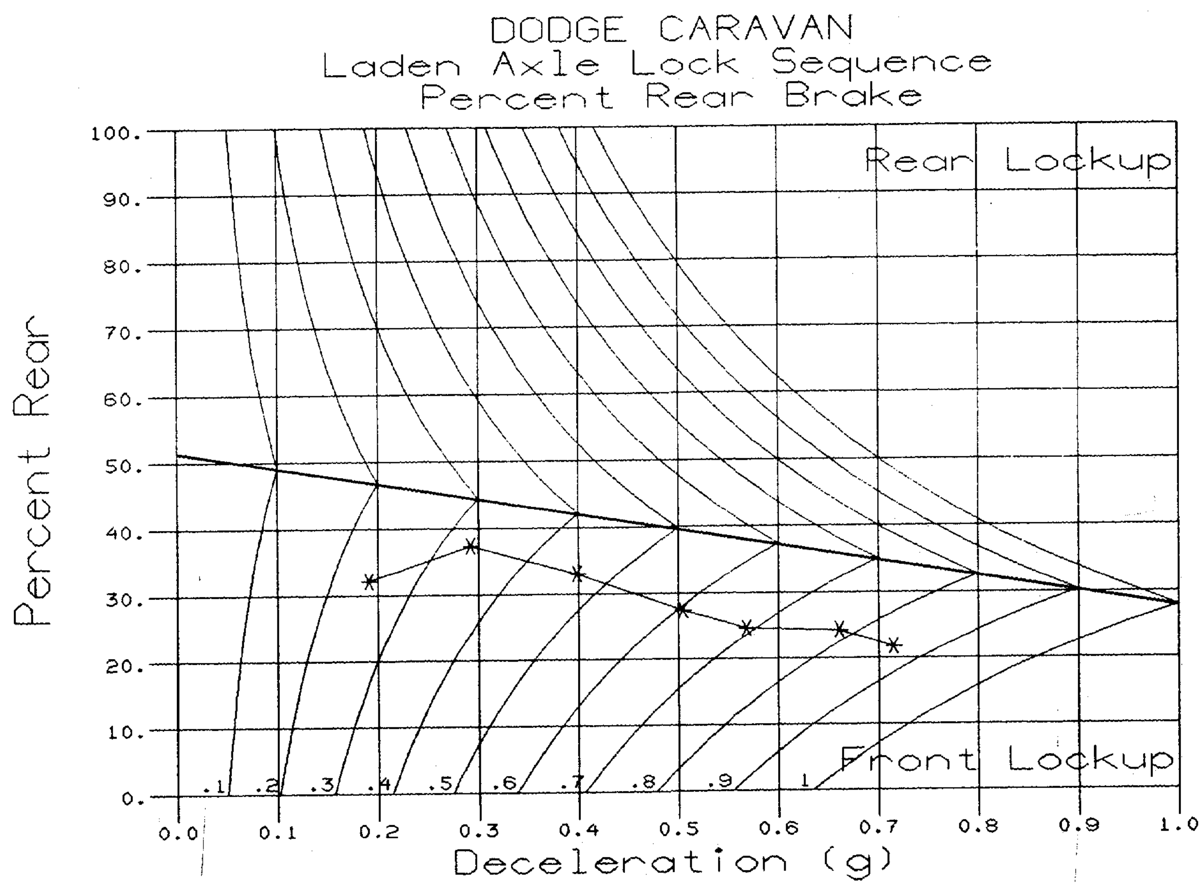
APPENDIX D

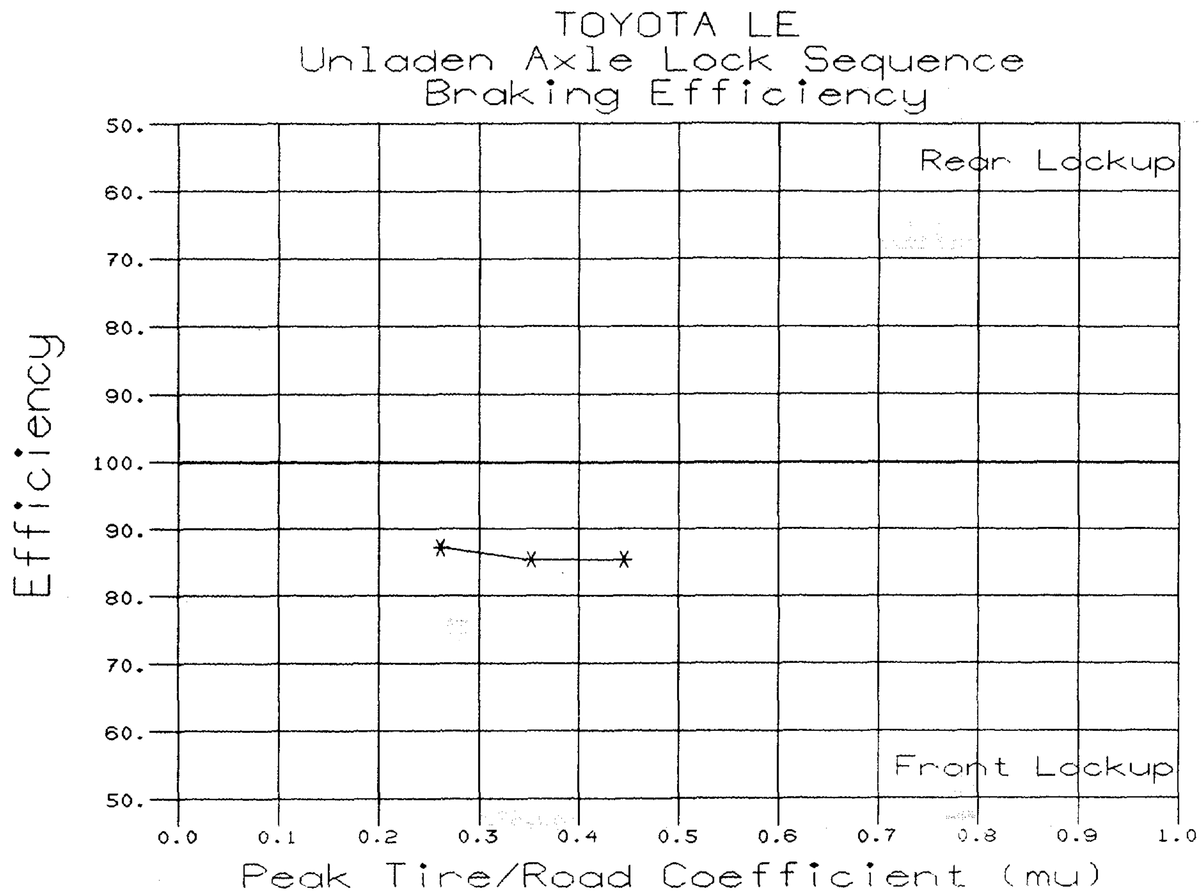
RTP Axle Lock Sequence Tests

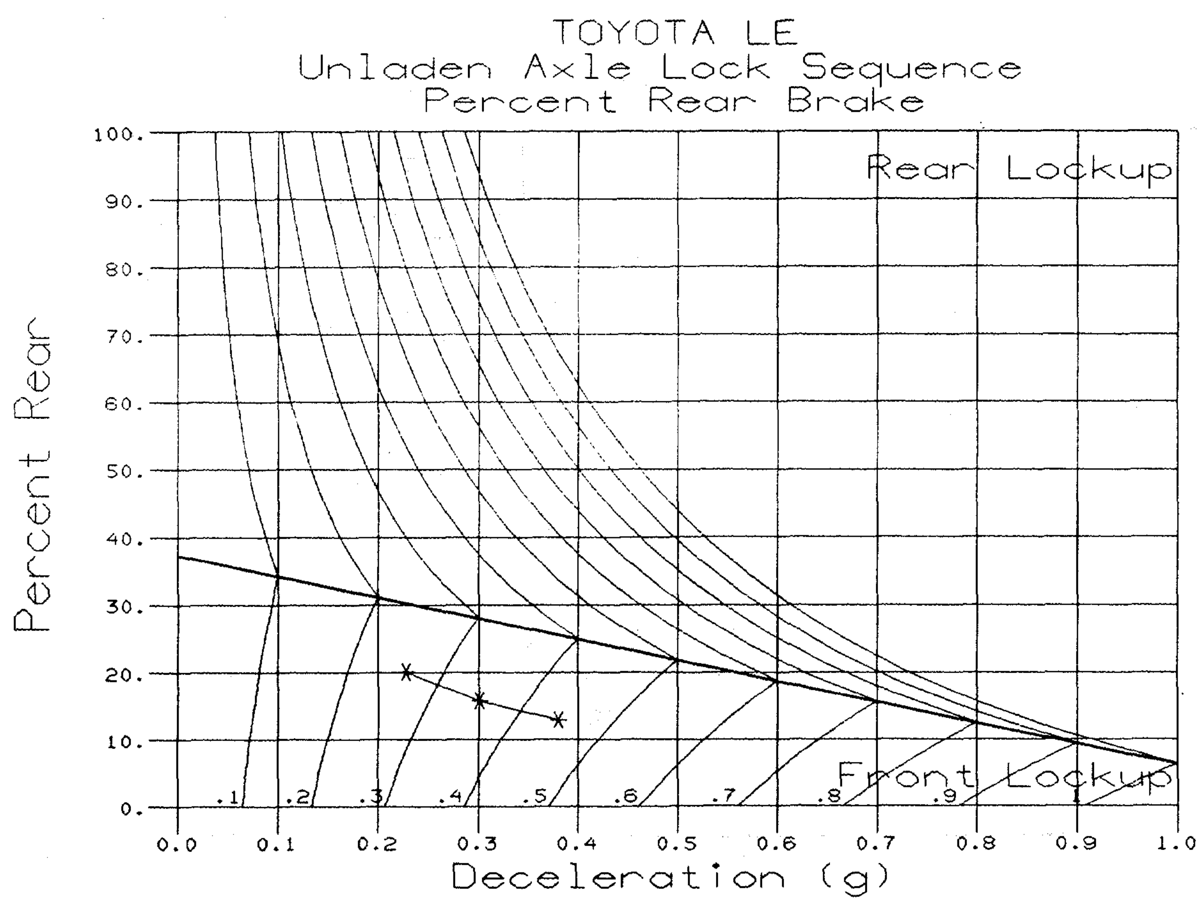

DODGE CARAVAN
Unladen Axle Lock Sequence
Braking Efficiency
Rear Lockup
Front Lockup
Efficiency
50.
60.
70.
80.
90.
100.
90.
80.
70.
60.
50.
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Peak Tire/Road Coefficient (mu)


DODGE CARAVAN
Unladen Axle Lock Sequence
Percent Rear Brake
Rear Lockup
Front Lockup
Percent Rear
100.
90.
80.
70.
60.
50.
40.
30.
20.
10.
0.
.1
.2
.3
.4
.5
.6
.7
.8
.9
1
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Deceleration (g)


DODGE CARAVAN
Laden Axle Lock Sequence
Braking Efficiency
Rear Lockup
Front Lockup
Efficiency
50.
60.
70.
80.
90.
100.
90.
80.
70.
60.
50.
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Peak Tire/Road Coefficient (mu)


DODGE CARAVAN
Laden Axle Lock Sequence
Percent Rear Brake
Rear Lockup
Front Lockup
Percent Rear
100.
90.
80.
70.
60.
50.
40.
30.
20.
10.
0.
.1
.2
.3
.4
.5
.6
.7
.8
.9
1
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Deceleration (g)


TOYOTA LE
Unladen Axle Lock Sequence
Braking Efficiency
Rear Lockup
Front Lockup
Efficiency
50.
60.
70.
80.
90.
100.
90.
80.
70.
60.
50.
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Peak Tire/Road Coefficient (mu)


TOYOTA LE
Unladen Axle Lock Sequence
Percent Rear Brake
Rear Lockup
Front Lockup
Percent Rear
100.
90.
80.
70.
60.
50.
40.
30.
20.
10.
0.
.1
.2
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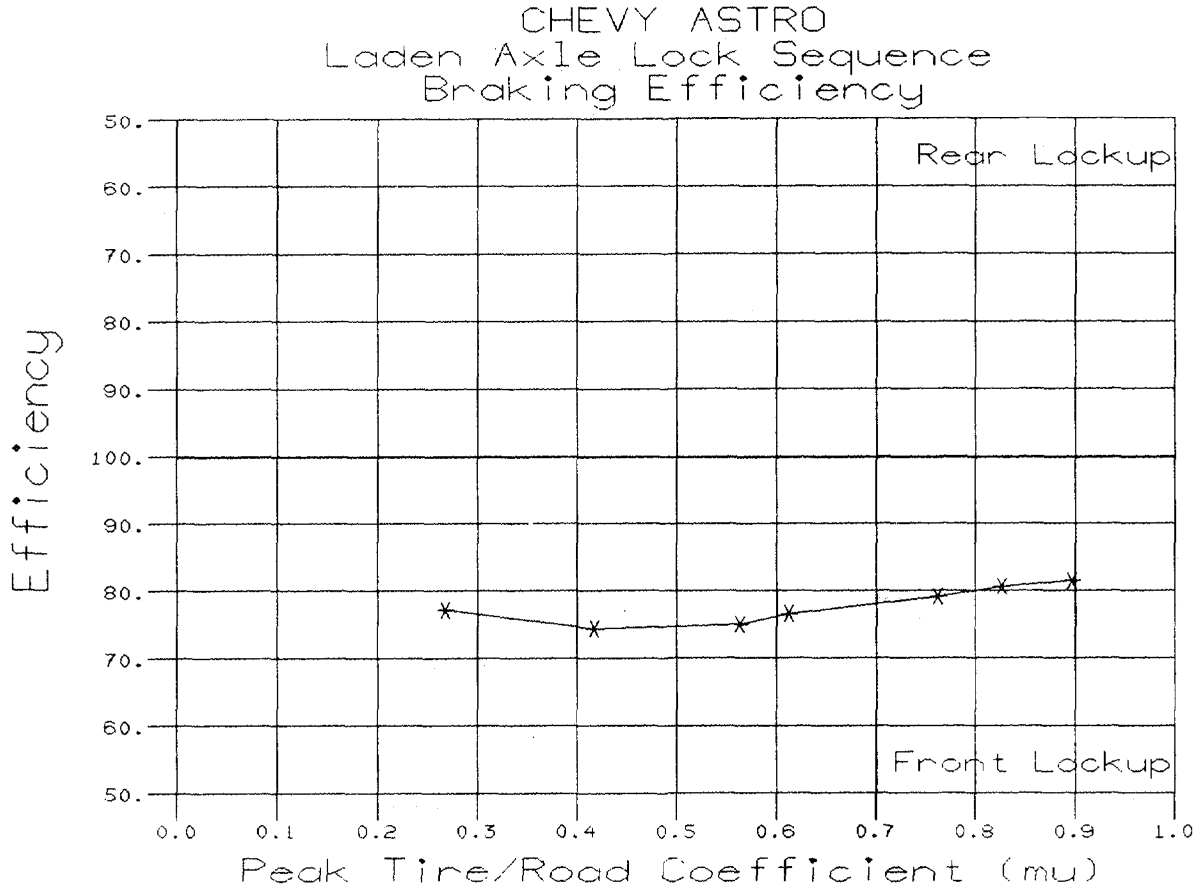
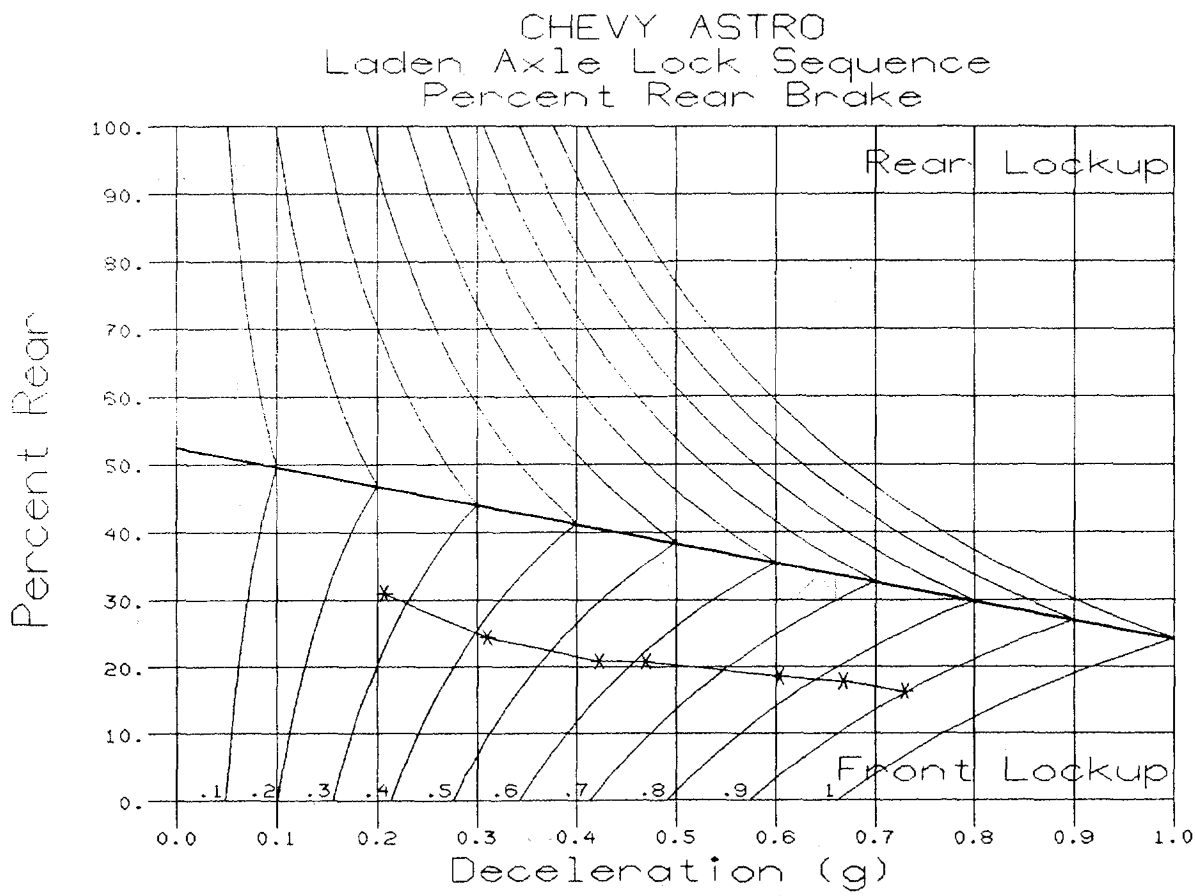
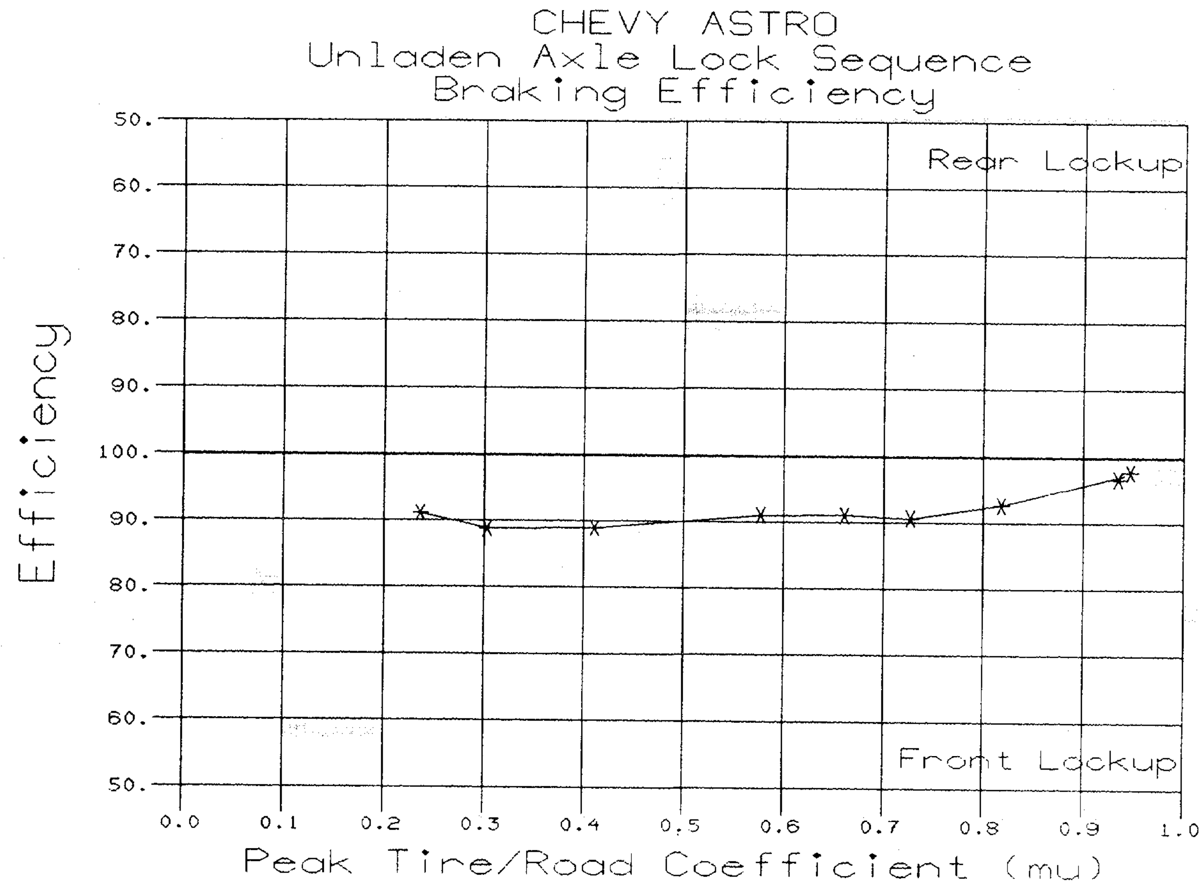
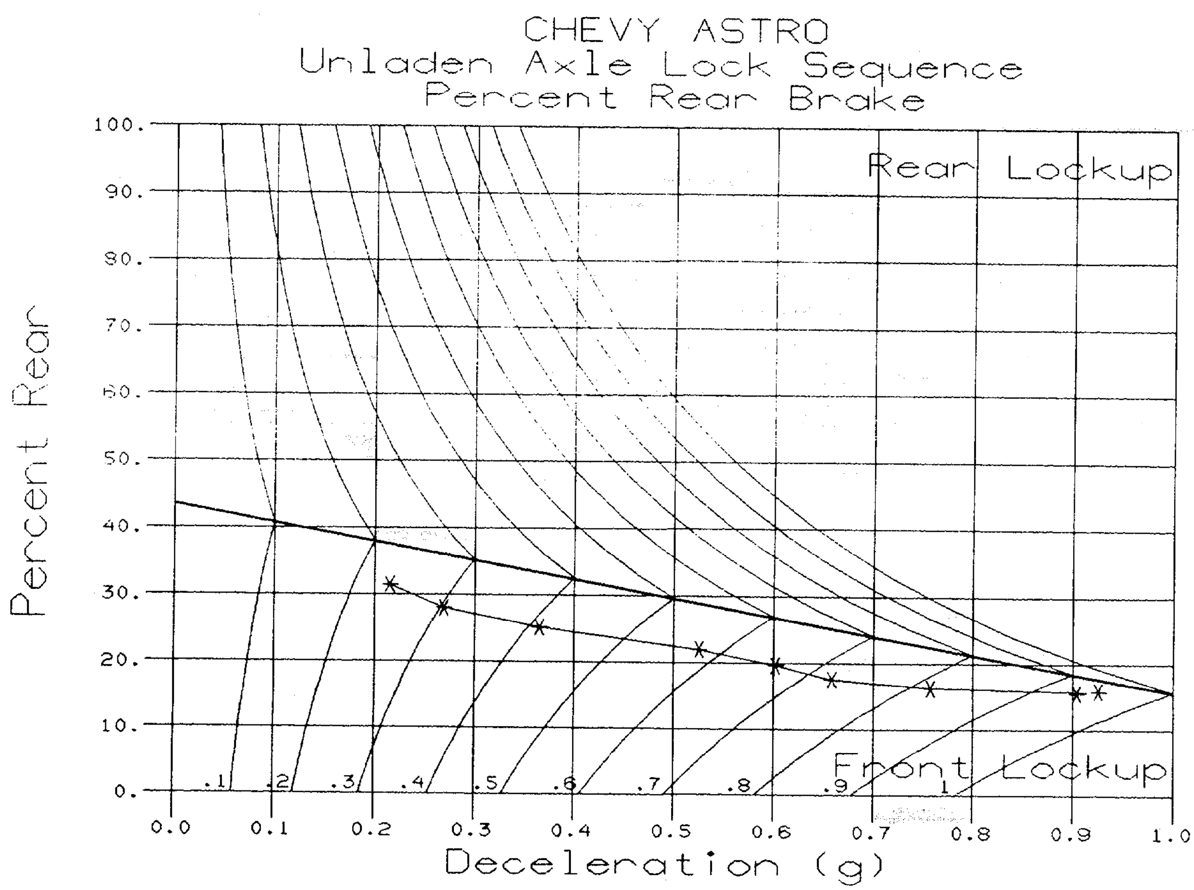
.6
.7
.8
.9
1
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Deceleration (g)


CHEVY ASTRO
Laden Axle Lock Sequence
Braking Efficiency
Rear Lockup
Front Lockup
Efficiency
50.
60.
70.
80.
90.
100.
90.
80.
70.
60.
50.
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Peak Tire/Road Coefficient (mu)


CHEVY ASTRO
Laden Axle Lock Sequence
Percent Rear Brake
Rear Lockup
Front Lockup
Percent Rear
100.
90.
80.
70.
60.
50.
40.
30.
20.
10.
0.
.1
.2
.3
.4
.5
.6
.7
.8
.9
1
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Deceleration (g)


CHEVY ASTRO
Unladen Axle Lock Sequence
Braking Efficiency
Rear Lockup
Front Lockup
Efficiency
50.
60.
70.
80.
90.
100.
90.
80.
70.
60.
50.
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Peak Tire/Road Coefficient (mu)


CHEVY ASTRO
Unladen Axle Lock Sequence
Percent Rear Brake
Rear Lockup
Front Lockup
Percent Rear
100.
90.
80.
70.
60.
50.
40.
30.
20.
10.
0.
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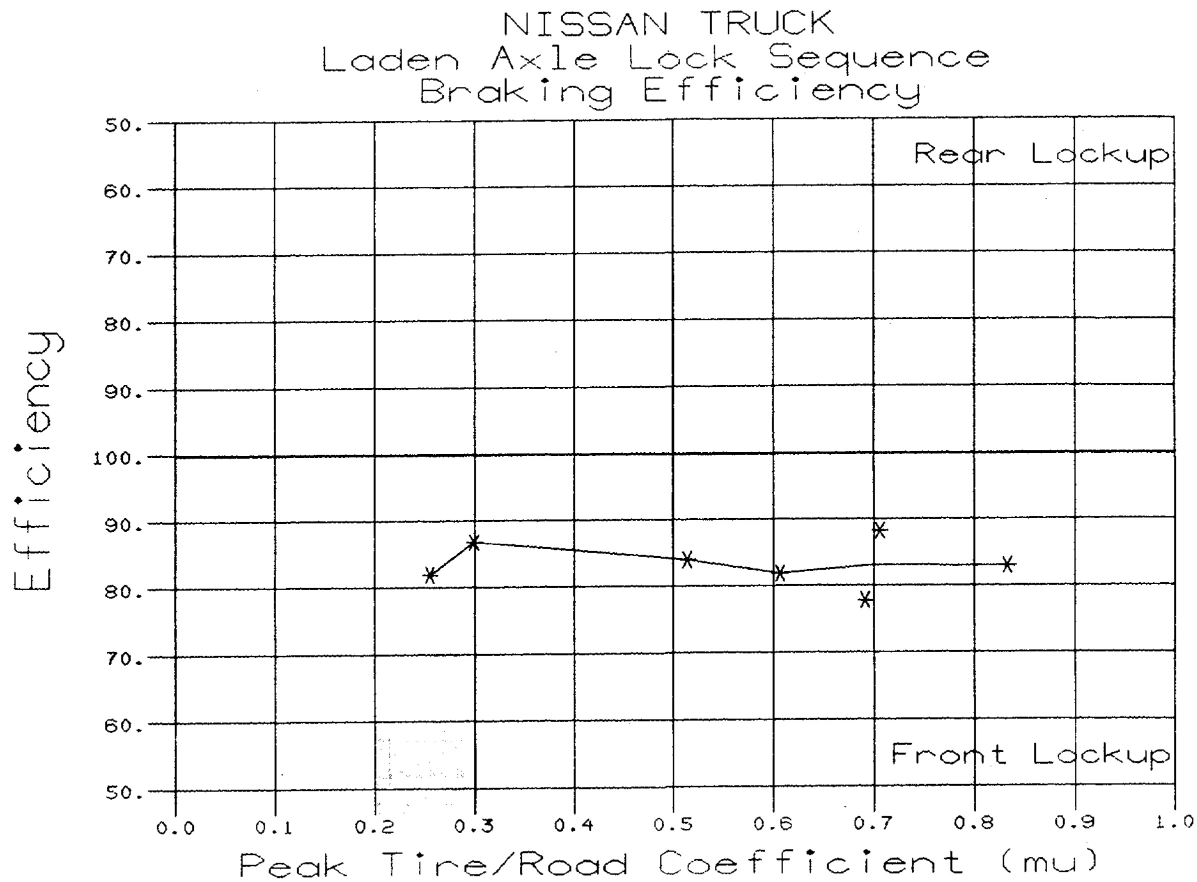
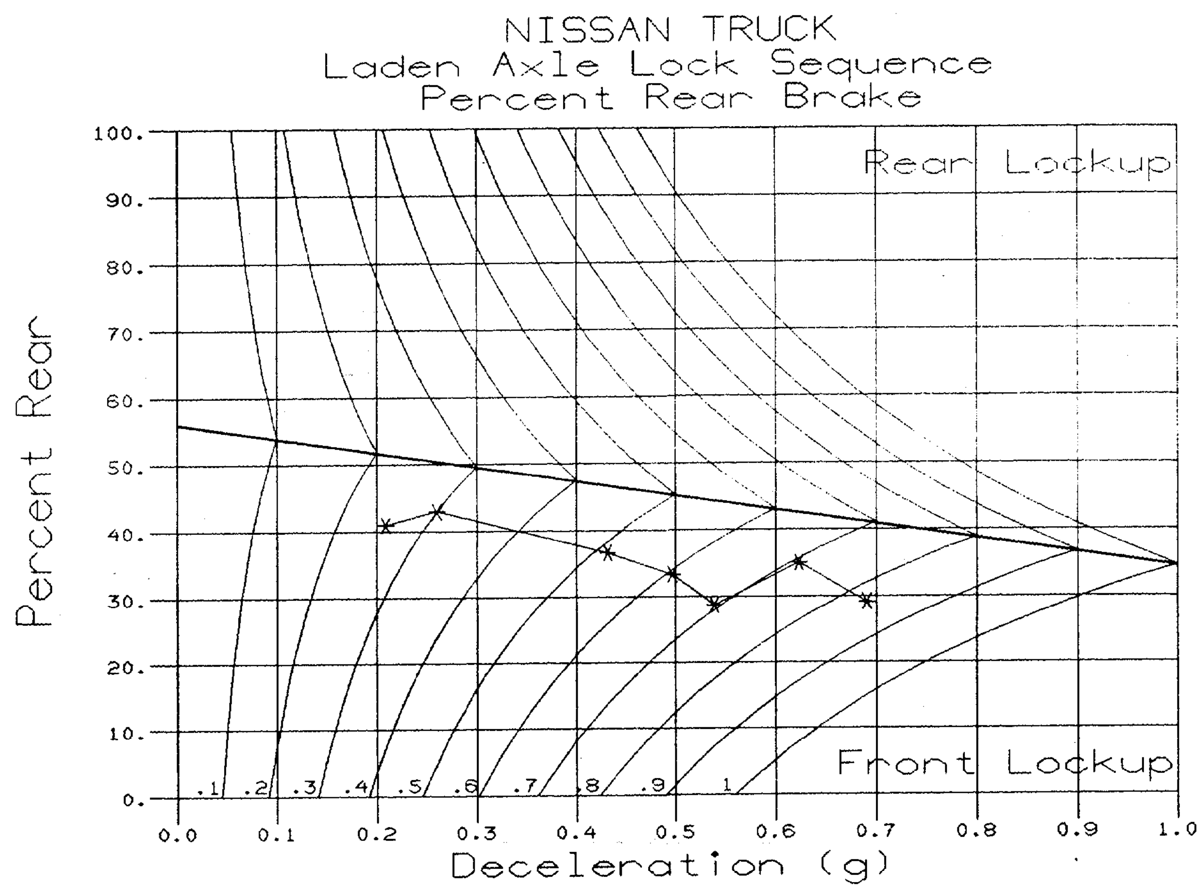
.9
1
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Deceleration (g)


NISSAN TRUCK
Laden Axle Lock Sequence
Braking Efficiency
Rear Lockup
Front Lockup
Efficiency
50.
60.
70.
80.
90.
100.
90.
80.
70.
60.
50.
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Peak Tire/Road Coefficient (mu)


NISSAN TRUCK
Laden Axle Lock Sequence
Percent Rear Brake
Rear Lockup
Front Lockup
Percent Rear
100.
90.
80.
70.
60.
50.
40.
30.
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10.
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.8
.9
1
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0.1
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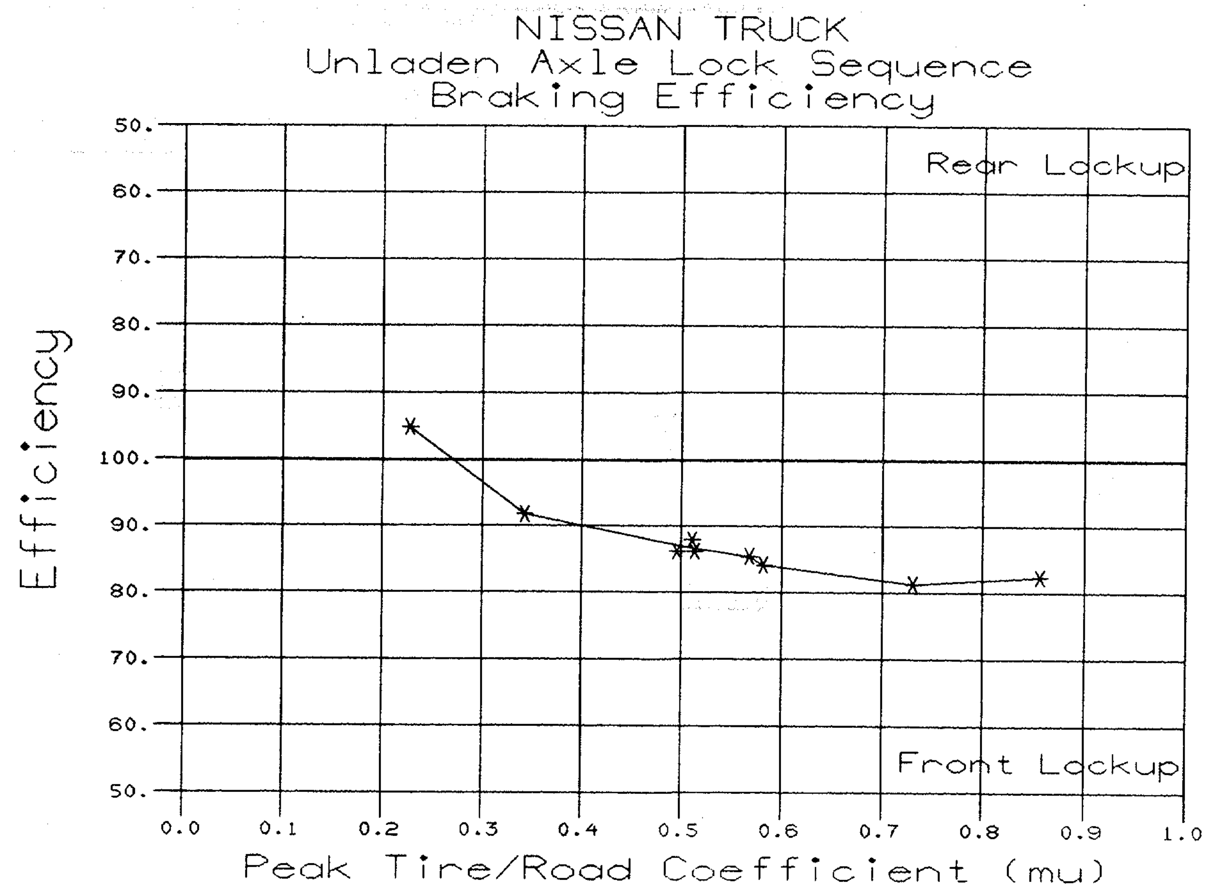
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Deceleration (g)


NISSAN TRUCK
Unladen Axle Lock Sequence
Braking Efficiency
Rear Lockup
Front Lockup
Efficiency
50.
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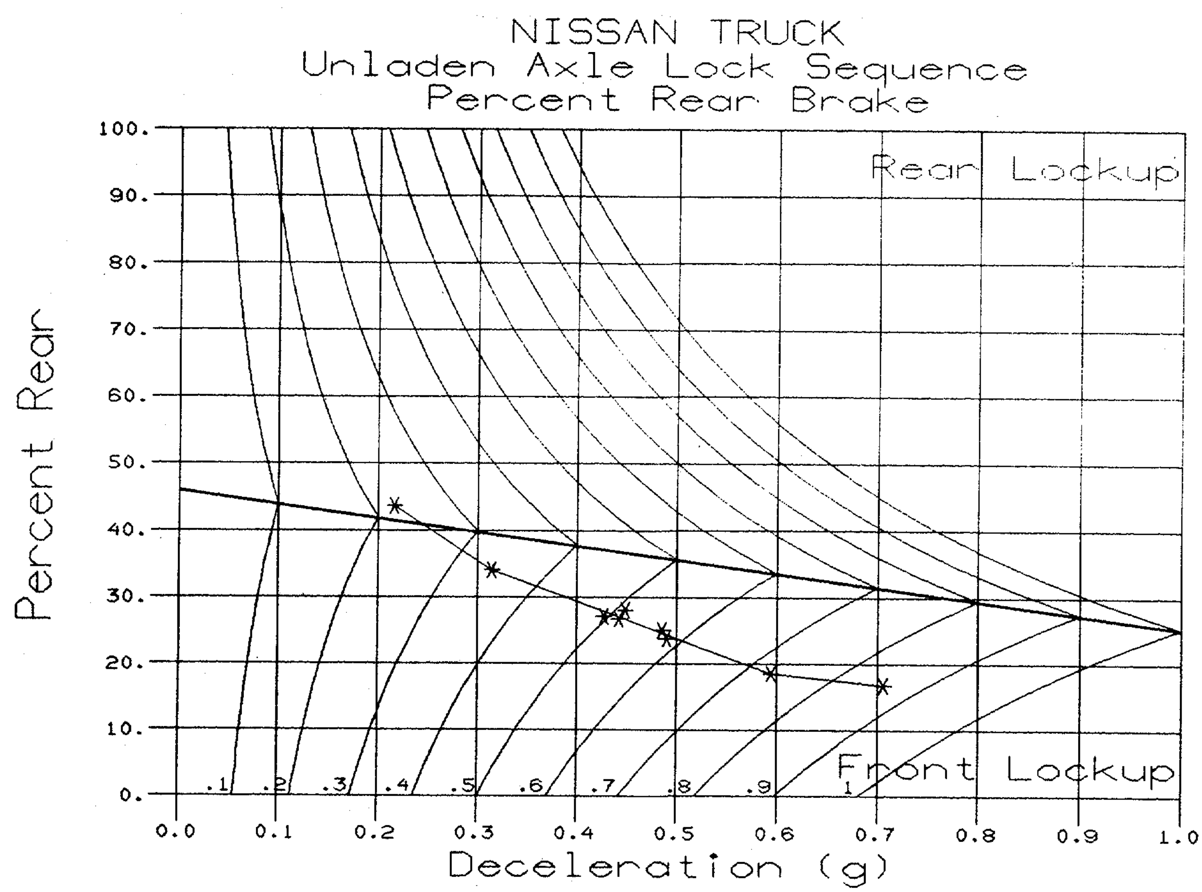
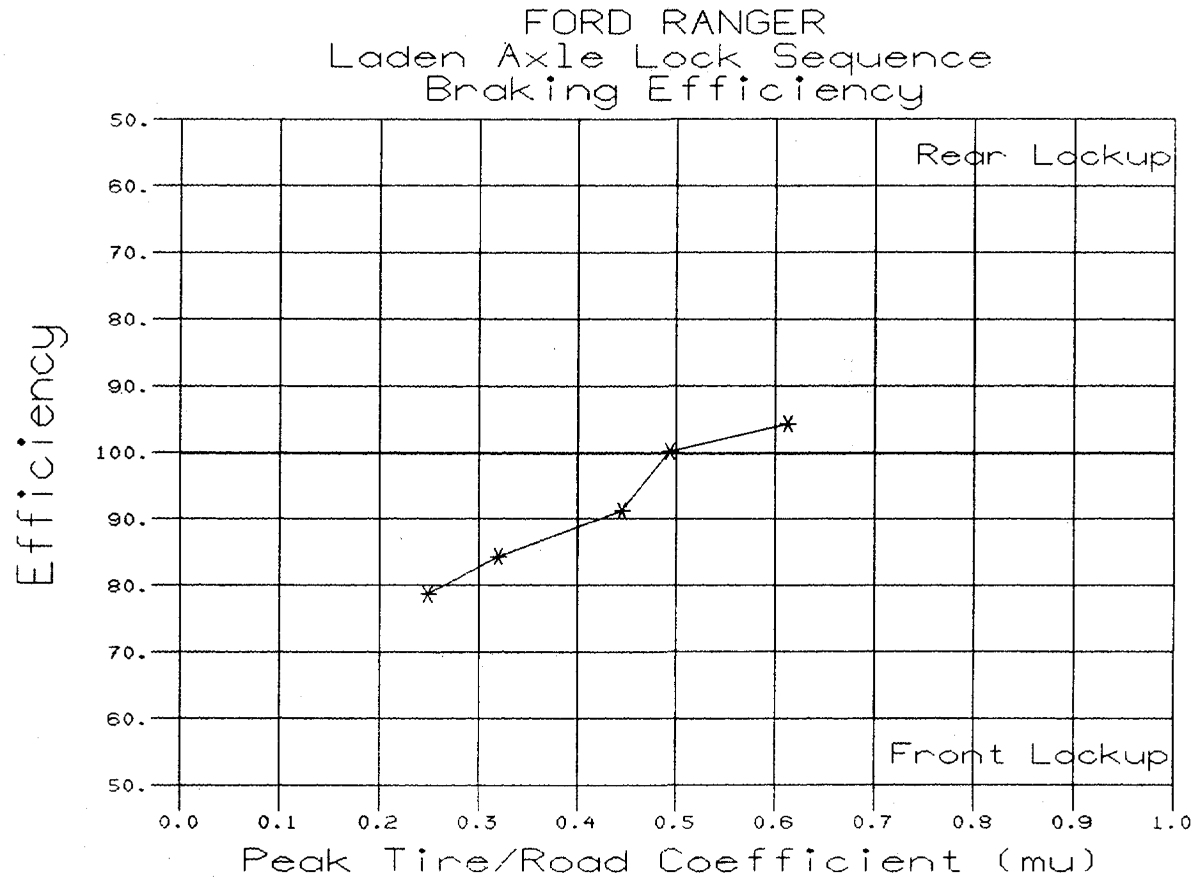
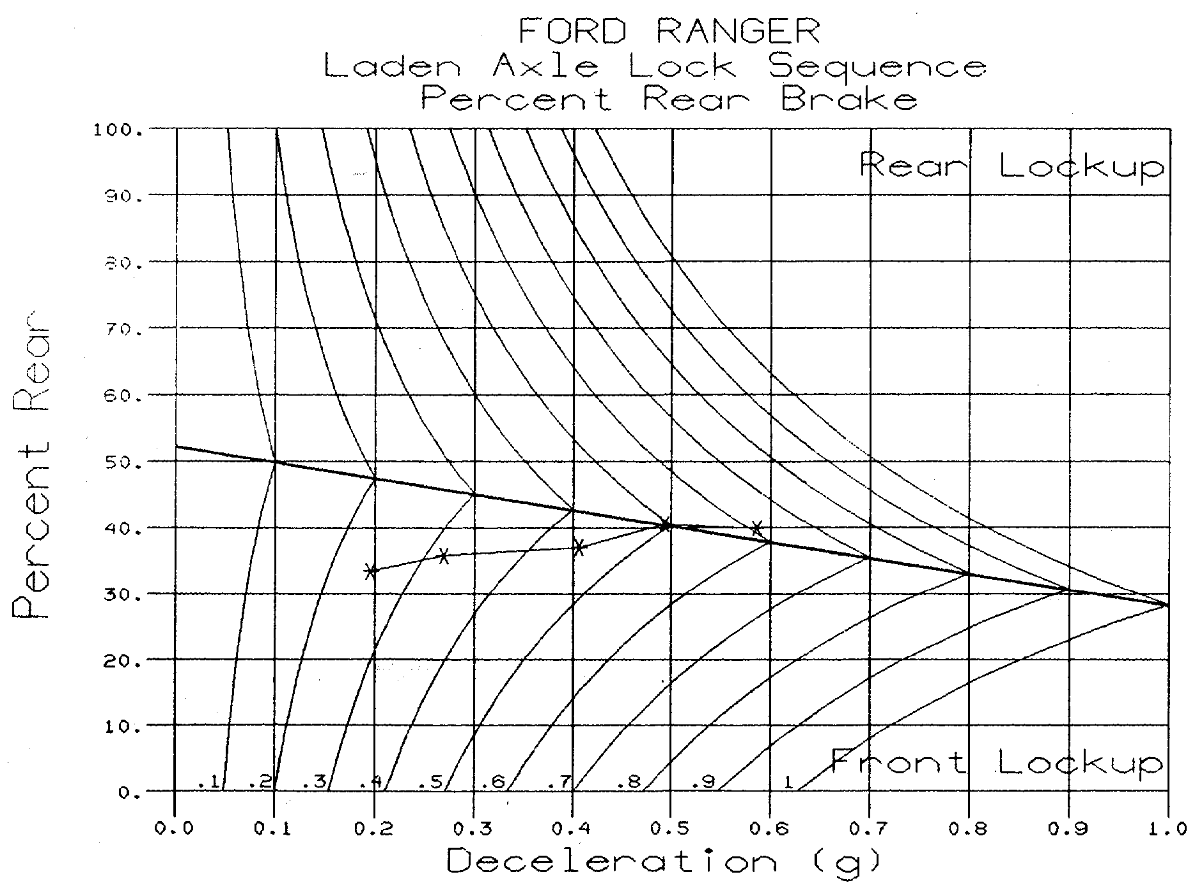
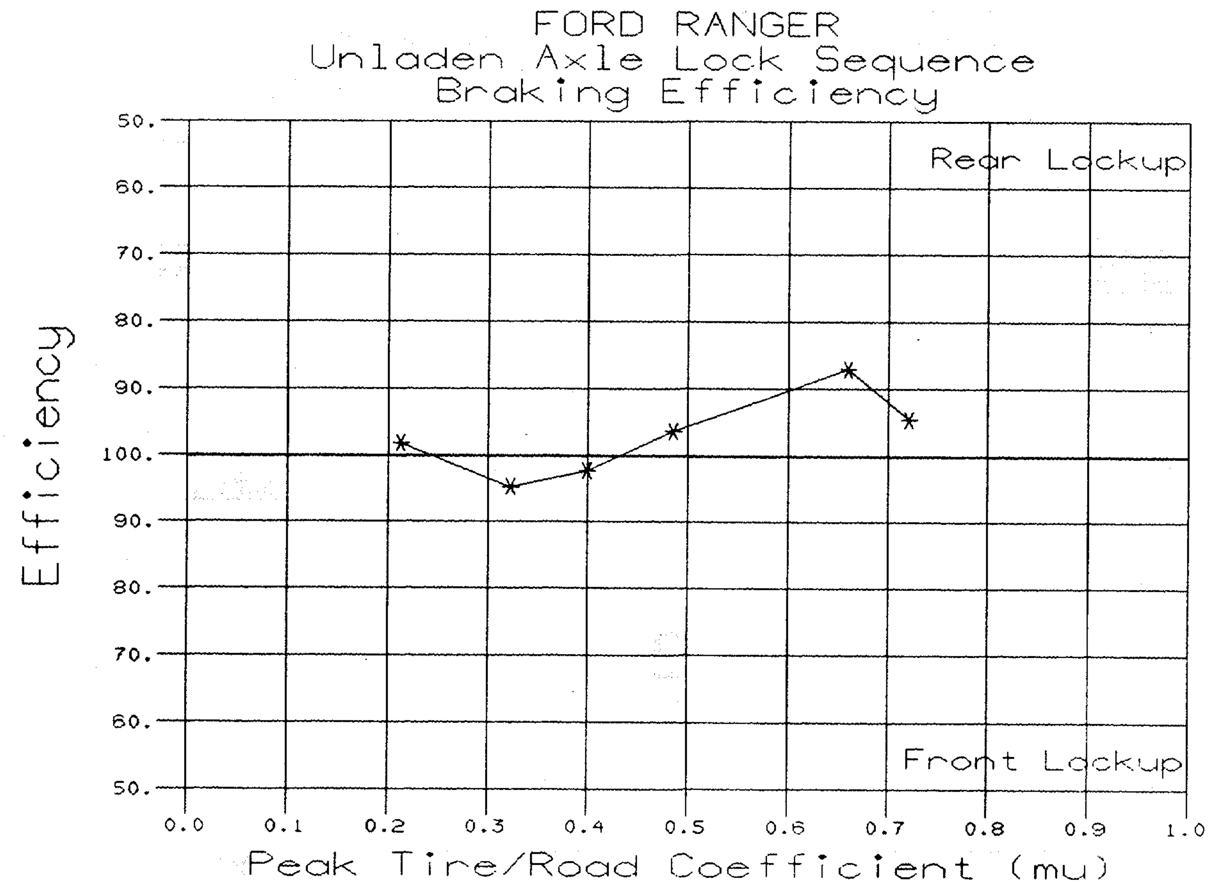
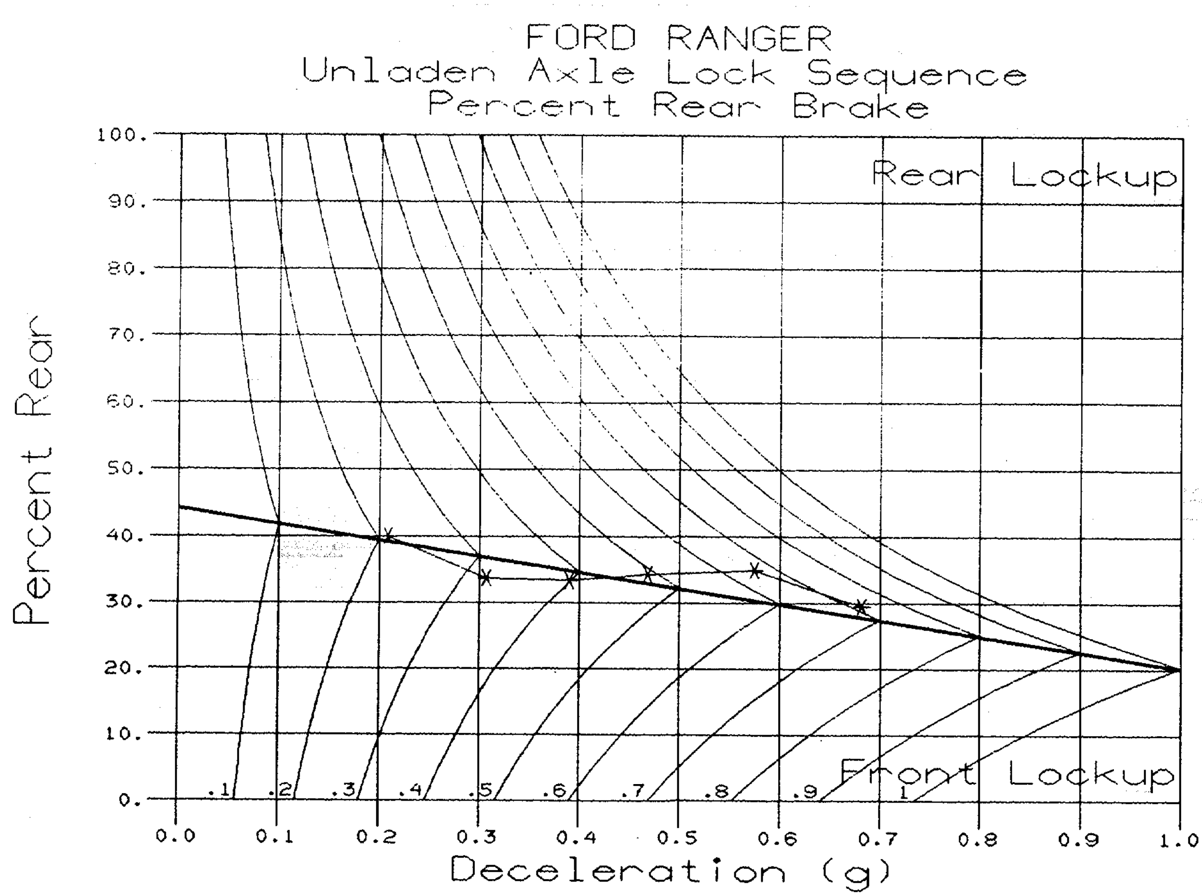
70.
80.
90.
100.
90.
80.
70.
60.
50.
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Peak Tire/Road Coefficient (mu)

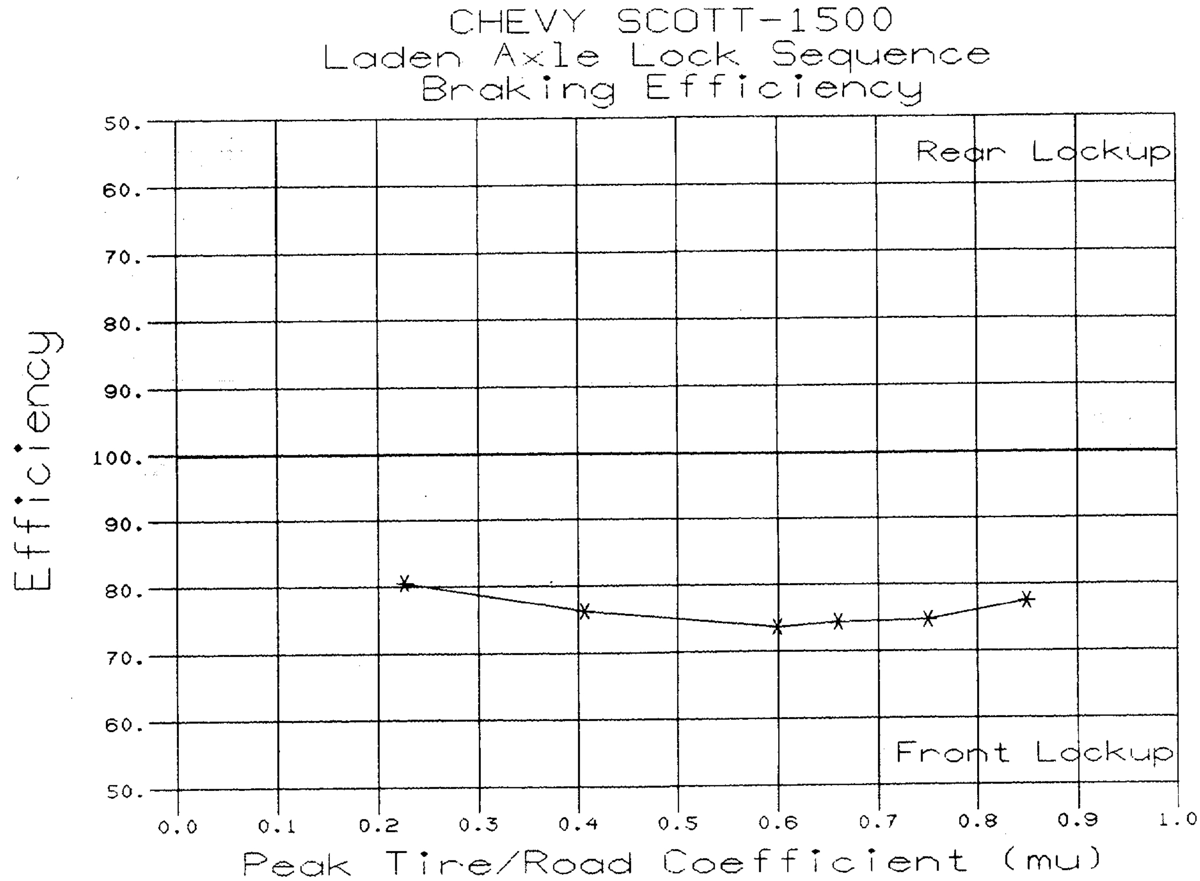

NISSAN TRUCK
Unladen Axle Lock Sequence
Percent Rear Brake
Rear Lockup
Front Lockup
Percent Rear
100.
90.
80.
70.
60.
50.
40.
30.
20.
10.
0.
.1
.2
.3
.4
.5
.6
.7
.8
.9
1
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Deceleration (g)

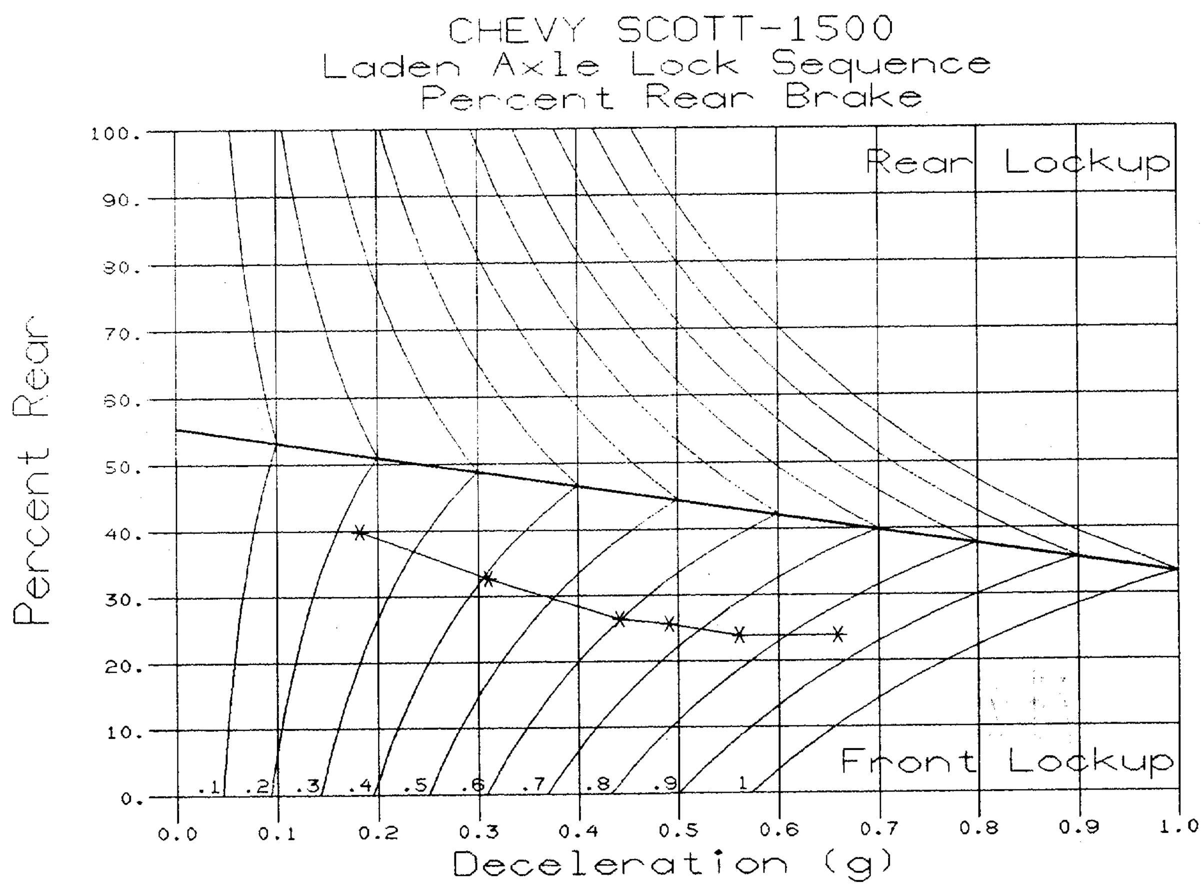

FORD RANGER
Laden Axle Lock Sequence
Braking Efficiency
Rear Lockup
Front Lockup
Efficiency
50.
60.
70.
80.
90.
100.
90.
80.
70.
60.
50.
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Peak Tire/Road Coefficient (mu)

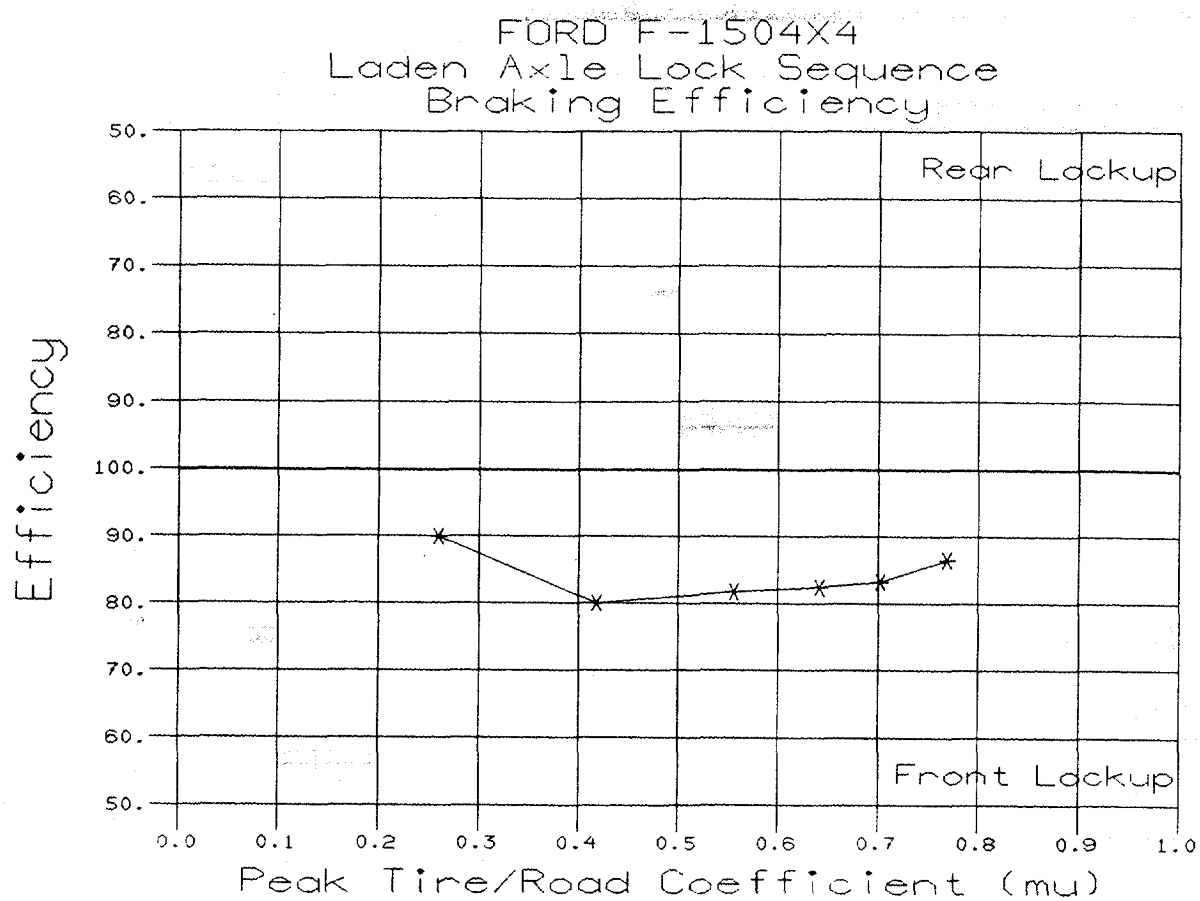

FORD RANGER
Laden Axle Lock Sequence
Percent Rear Brake
Rear Lockup
Front Lockup
Percent Rear
100.
90.
80.
70.
60.
50.
40.
30.
20.
10.
0.
.1
.2
.3
.4
.5
.6
.7
.8
.9
1
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Deceleration (g)

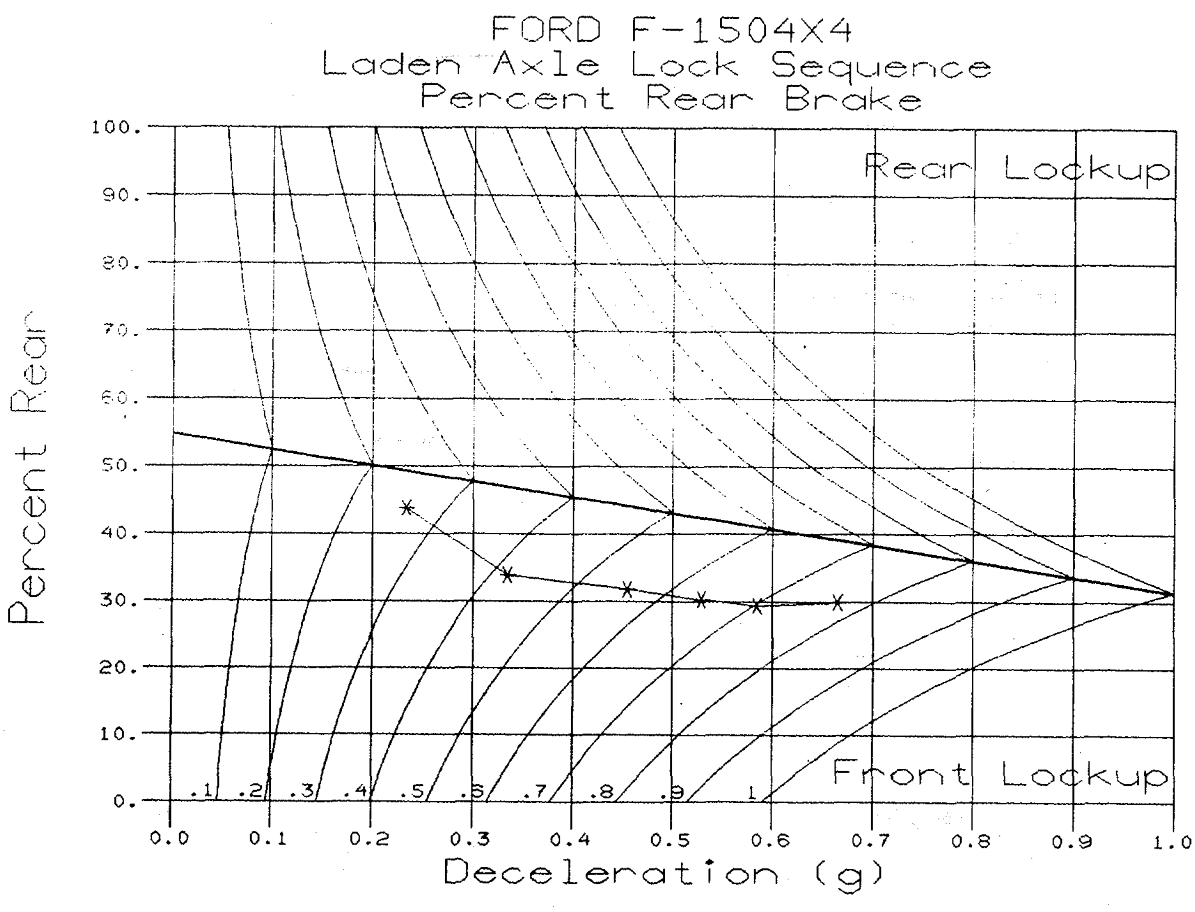

FORD RANGER
Unladen Axle Lock Sequence
Braking Efficiency
Rear Lockup
Front Lockup
Efficiency
50.
60.
70.
80.
90.
100.
90.
80.
70.
60.
50.
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Peak Tire/Road Coefficient (mu)

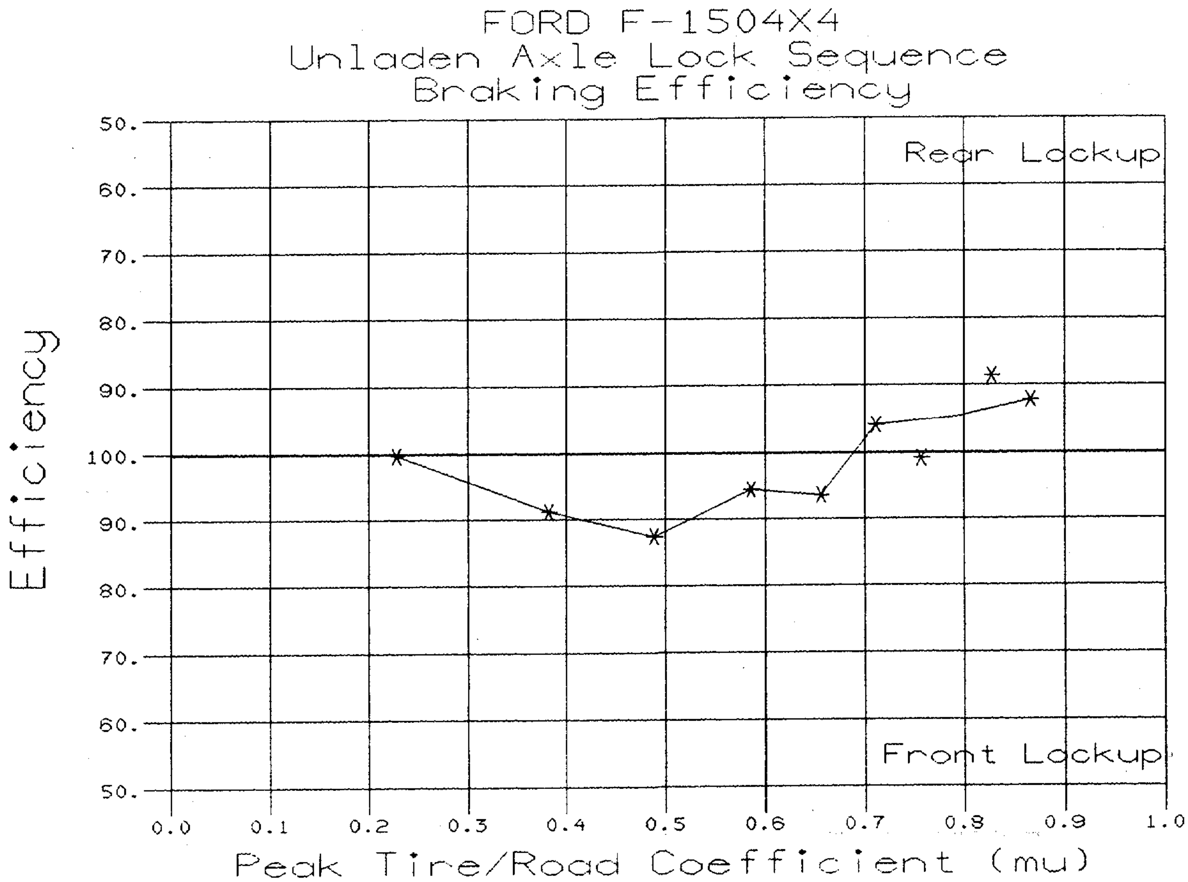

FORD RANGER
Unladen Axle Lock Sequence
Percent Rear Brake
Rear Lockup
Front Lockup
Percent Rear
100.
90.
80.
70.
60.
50.
40.
30.
20.
10.
0.
.1
.2
.3
.4
.5
.6
.7
.8
.9
1
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Deceleration (g)

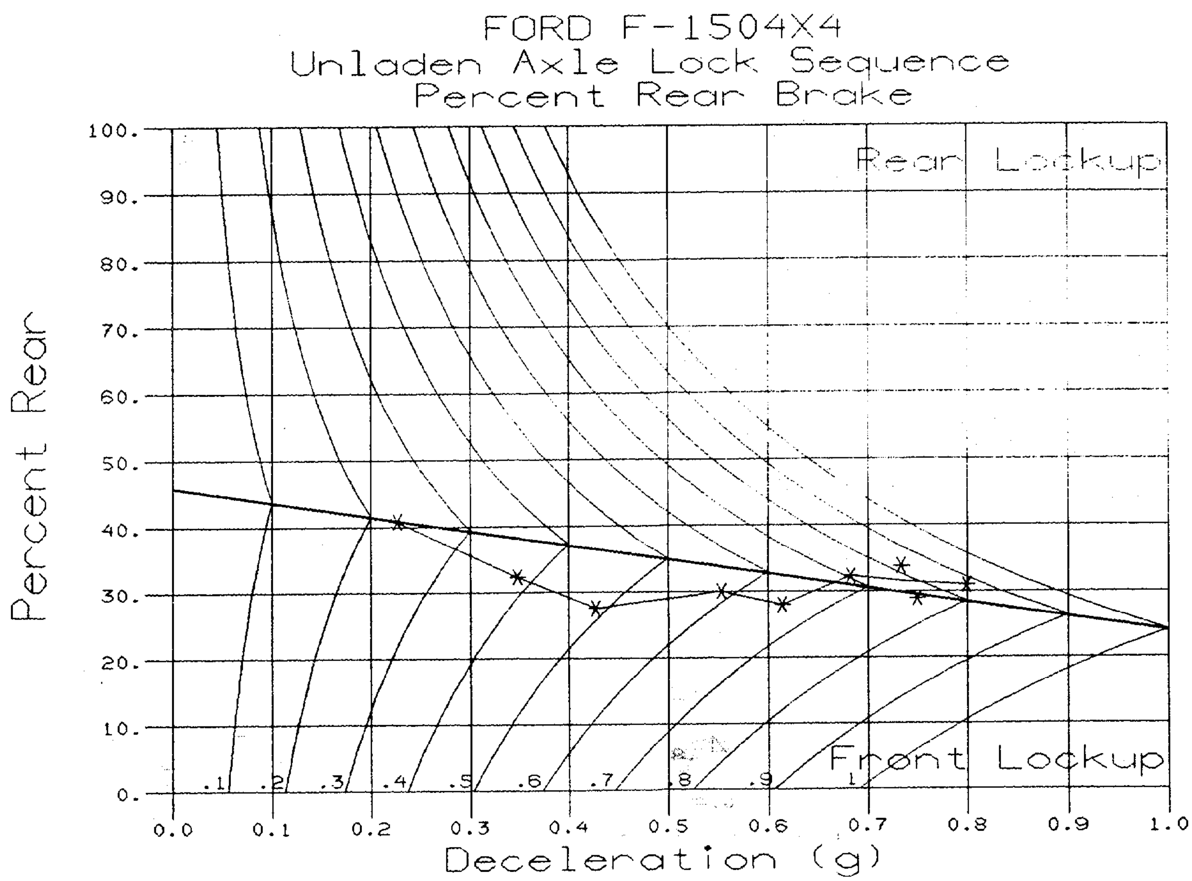

CHEVY SCOTT-1500
Laden Axle Lock Sequence
Braking Efficiency
Rear Lockup
Front Lockup
Efficiency
50.
60.
70.
80.
90.
100.
90.
80.
70.
60.
50.
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Peak Tire/Road Coefficient (mu)

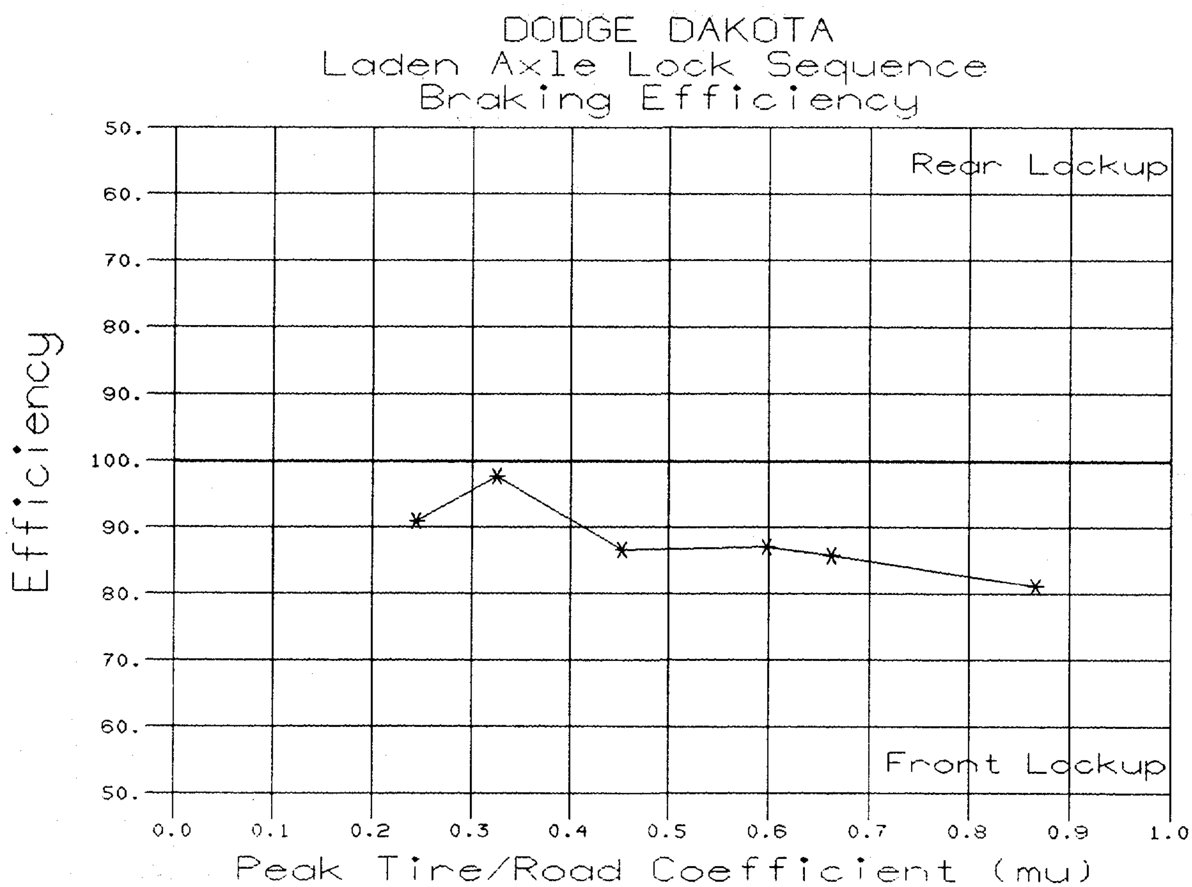

CHEVY SCOTT-1500
Laden Axle Lock Sequence
Percent Rear Brake
Rear Lockup
Front Lockup
Percent Rear
100.
90.
80.
70.
60.
50.
40.
30.
20.
10.
0.
.1
.2
.3
.4
.5
.6
.7
.8
.9
1
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Deceleration (g)

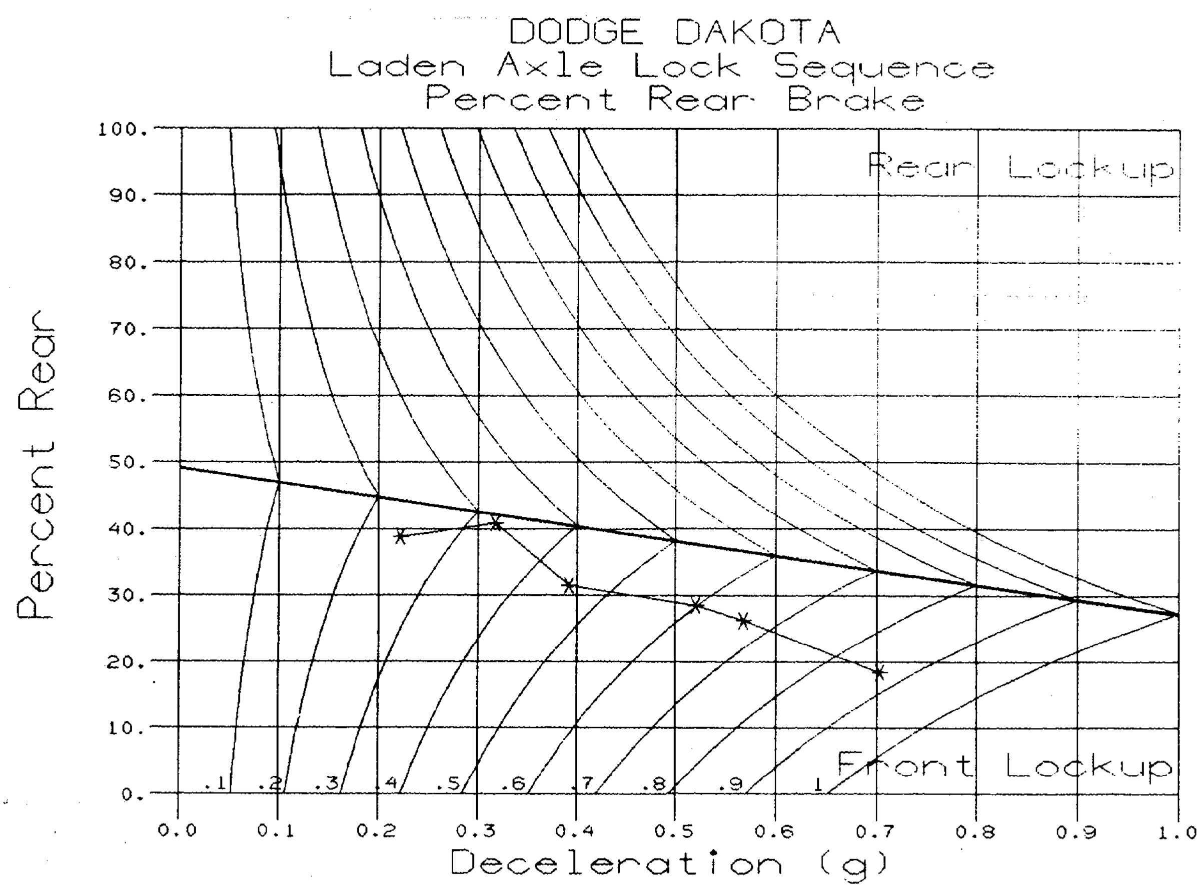

FORD F-1504X4
Laden Axle Lock Sequence
Braking Efficiency
Rear Lockup
Front Lockup
Efficiency
50.
60.
70.
80.
90.
100.
90.
80.
70.
60.
50.
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Peak Tire/Road Coefficient (mu)

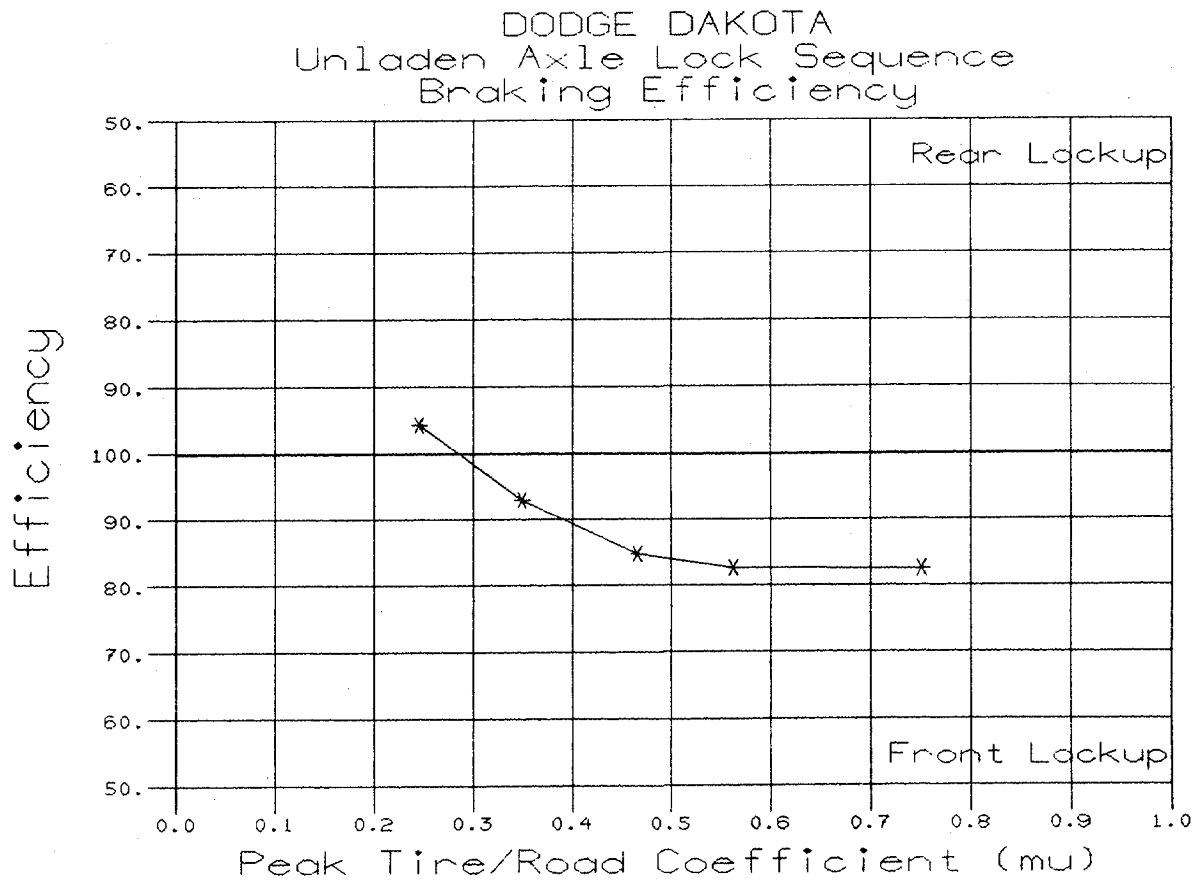

FORD F-1504X4
Laden Axle Lock Sequence
Percent Rear Brake
Rear Lockup
Front Lockup
Percent Rear
100.
90.
80.
70.
60.
50.
40.
30.
20.
10.
0.
.1
.2
.3
.4
.5
.6
.7
.8
.9
1
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Deceleration (g)

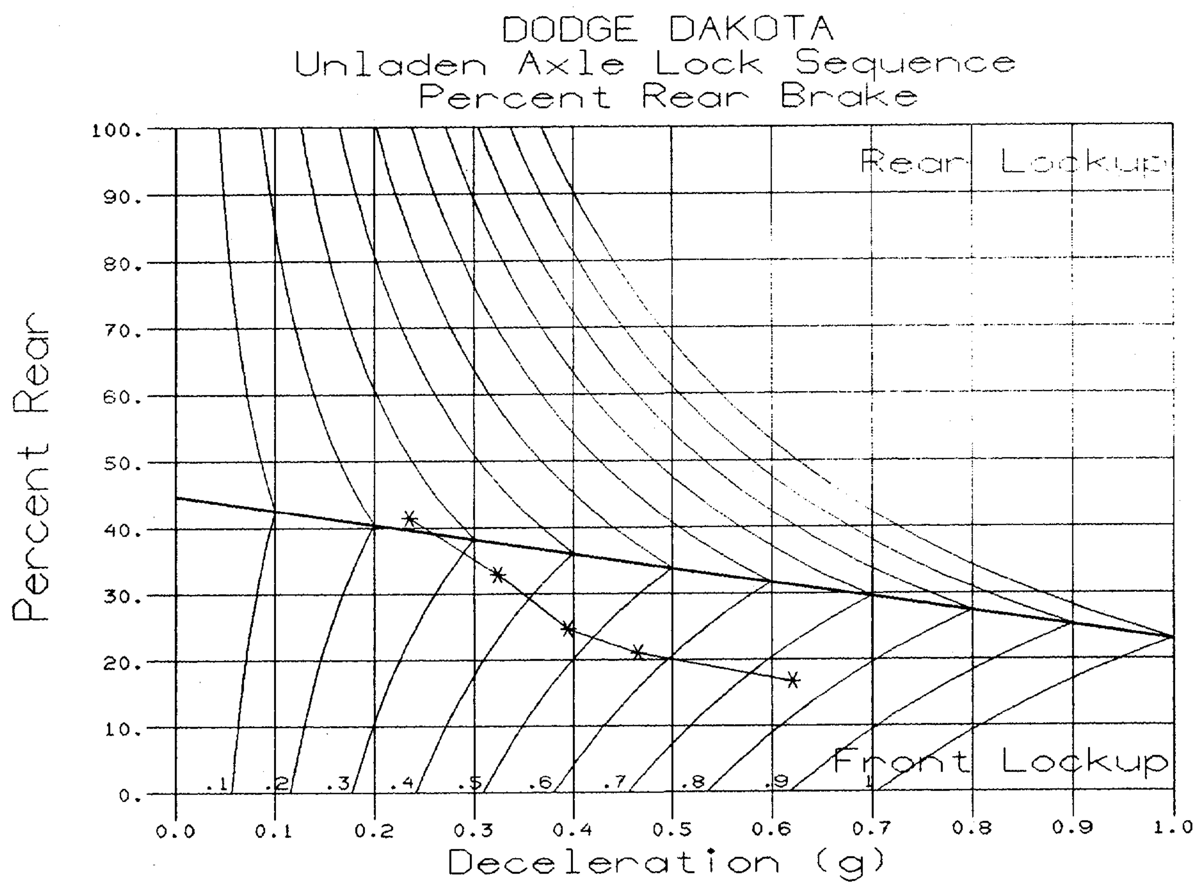

FORD F-1504X4
Unladen Axle Lock Sequence
Braking Efficiency
Rear Lockup
Front Lockup
Efficiency
50.
60.
70.
80.
90.
100.
90.
80.
70.
60.
50.
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Peak Tire/Road Coefficient (mu)

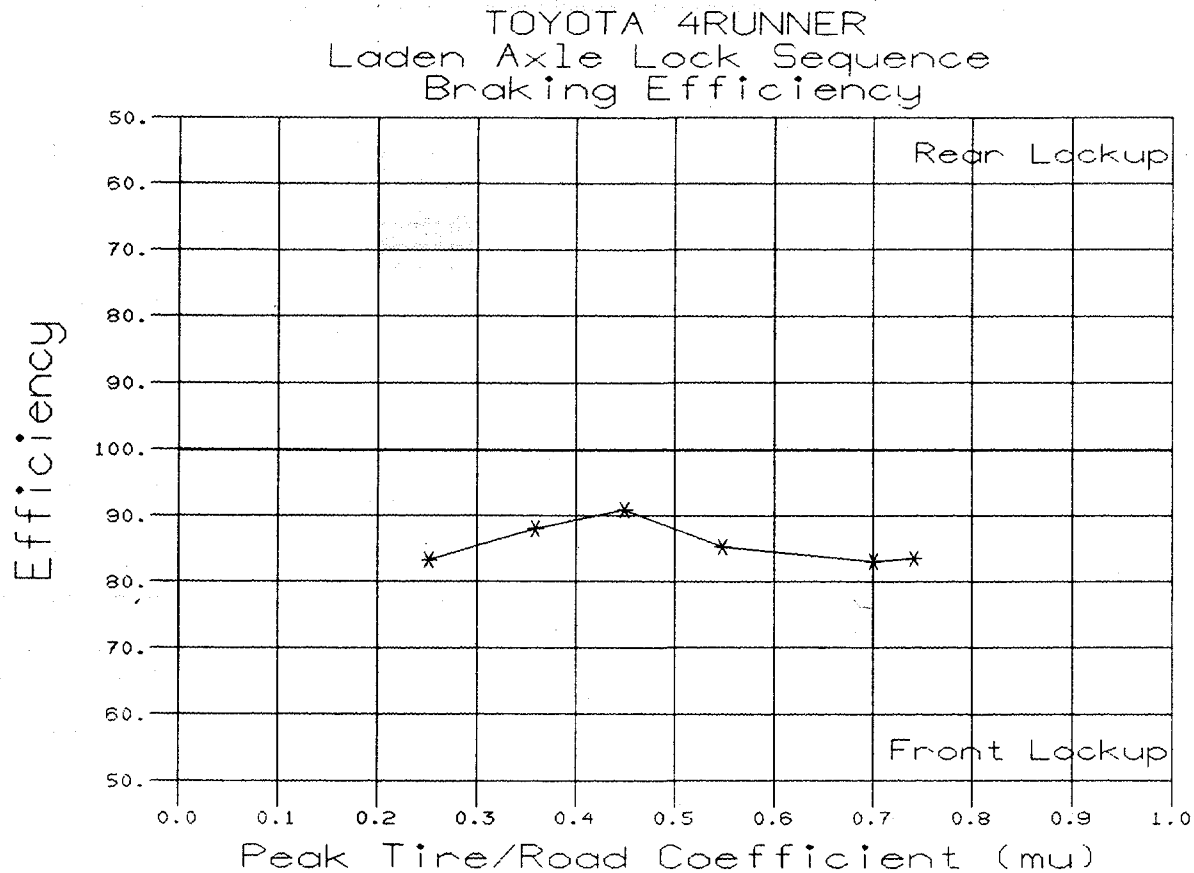

FORD F-1504X4
Unladen Axle Lock Sequence
Percent Rear Brake
Rear Lockup
Front Lockup
Percent Rear
100.
90.
80.
70.
60.
50.
40.
30.
20.
10.
0.
.1
.2
.3
.4
.5
.6
.7
.8
.9
1
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Deceleration (g)

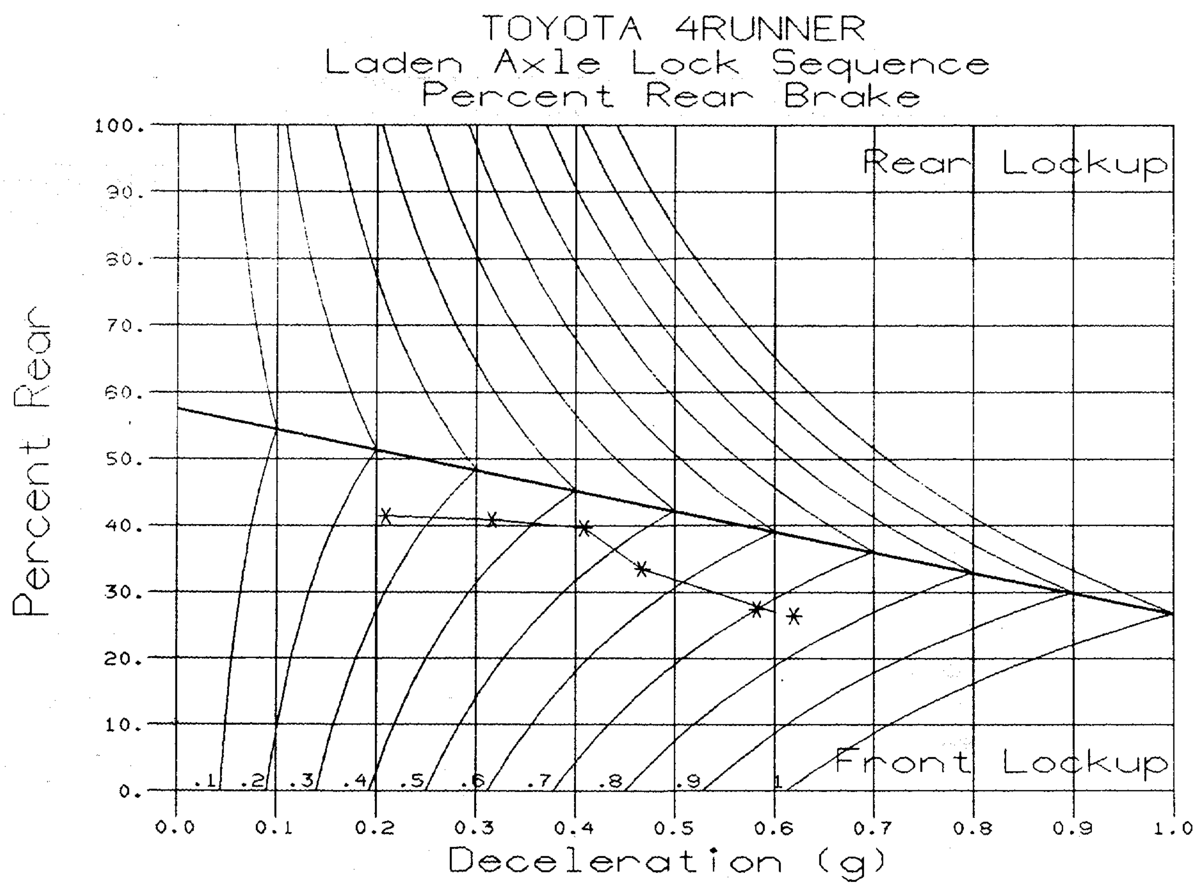

DODGE DAKOTA
Laden Axle Lock Sequence
Braking Efficiency
Rear Lockup
Front Lockup
Efficiency
50.
60.
70.
80.
90.
100.
90.
80.
70.
60.
50.
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Peak Tire/Road Coefficient (mu)

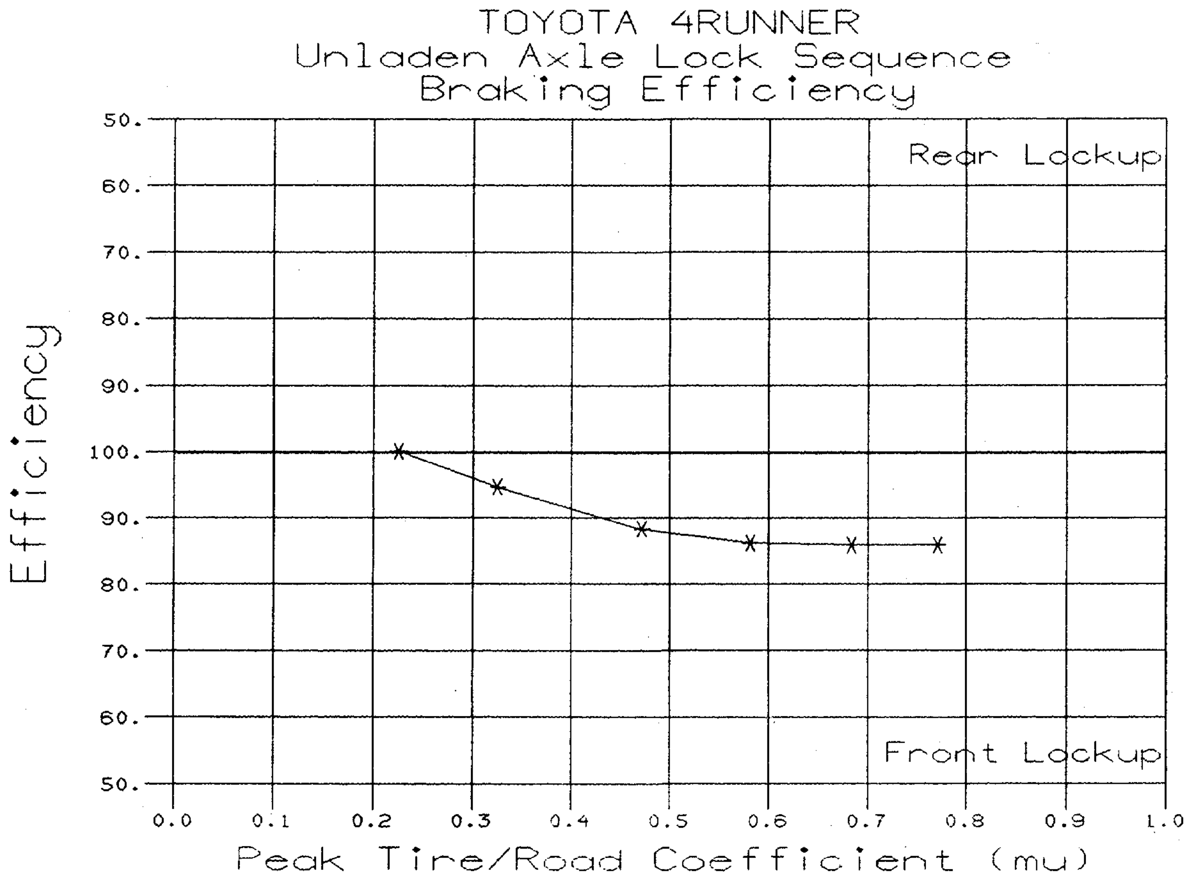

DODGE DAKOTA
Laden Axle Lock Sequence
Percent Rear Brake
Rear Lockup
Front Lockup
Percent Rear
100.
90.
80.
70.
60.
50.
40.
30.
20.
10.
0.
.1
.2
.3
.4
.5
.6
.7
.8
.9
1
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Deceleration (g)

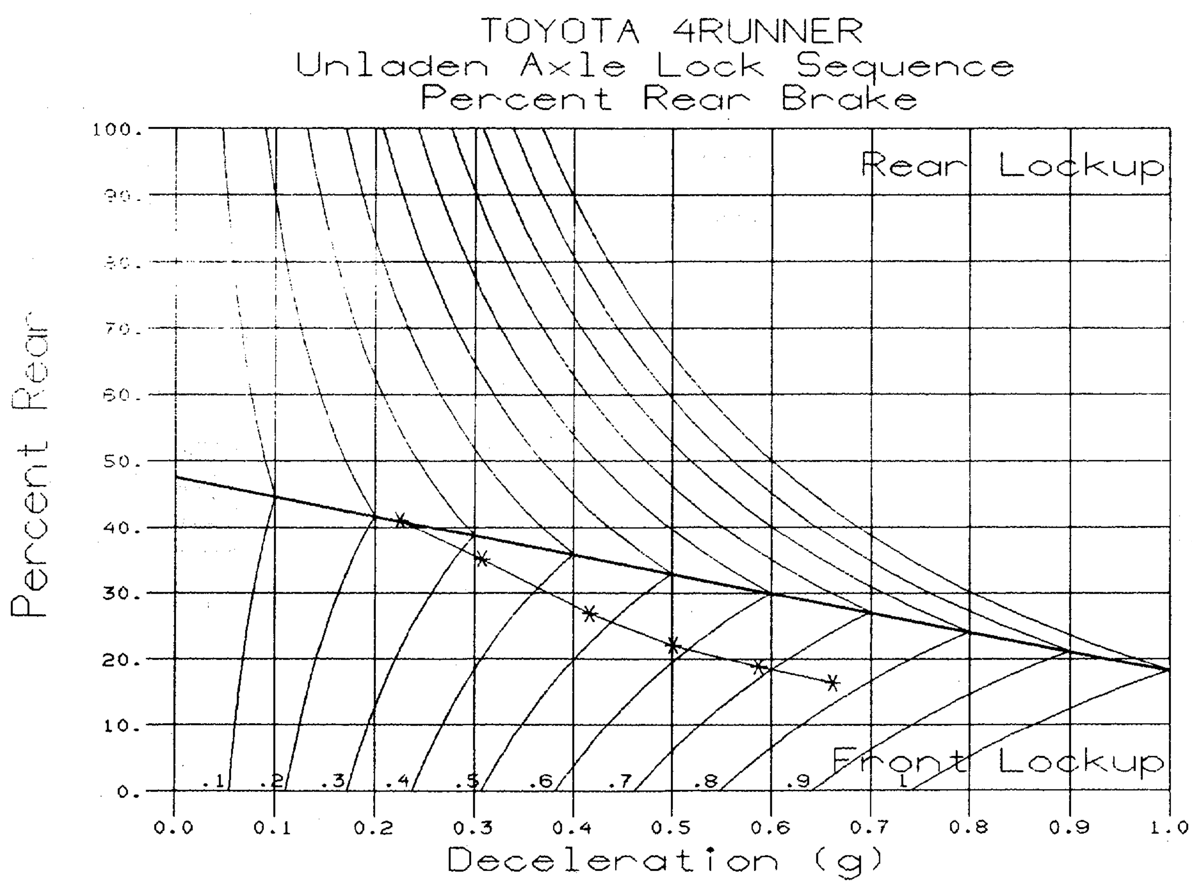

DODGE DAKOTA
Unladen Axle Lock Sequence
Braking Efficiency
Rear Lockup
Front Lockup
Efficiency
50.
60.
70.
80.
90.
100.
90.
80.
70.
60.
50.
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Peak Tire/Road Coefficient (mu)

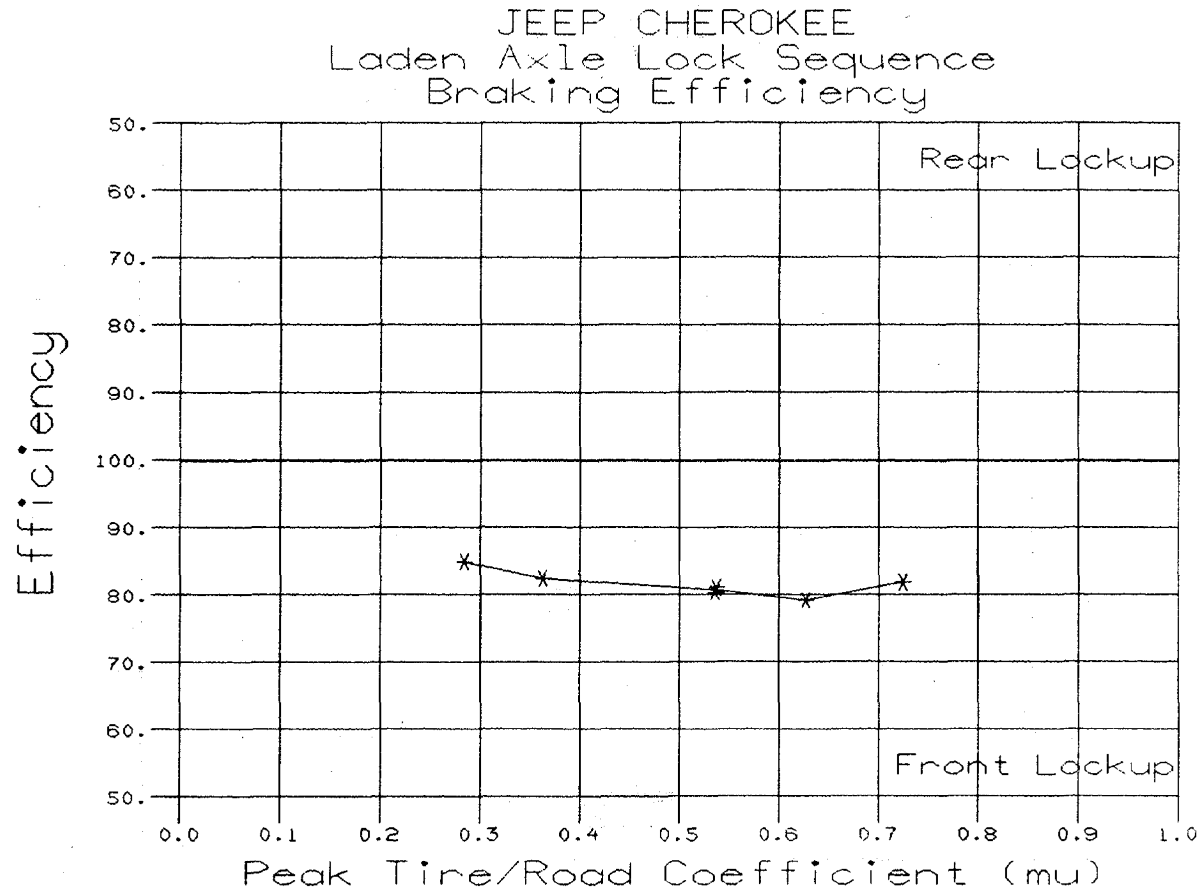

DODGE DAKOTA
Unladen Axle Lock Sequence
Percent Rear Brake
Rear Lockup
Front Lockup
Percent Rear
100.
90.
80.
70.
60.
50.
40.
30.
20.
10.
0.
.1
.2
.3
.4
.5
.6
.7
.8
.9
1
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Deceleration (g)

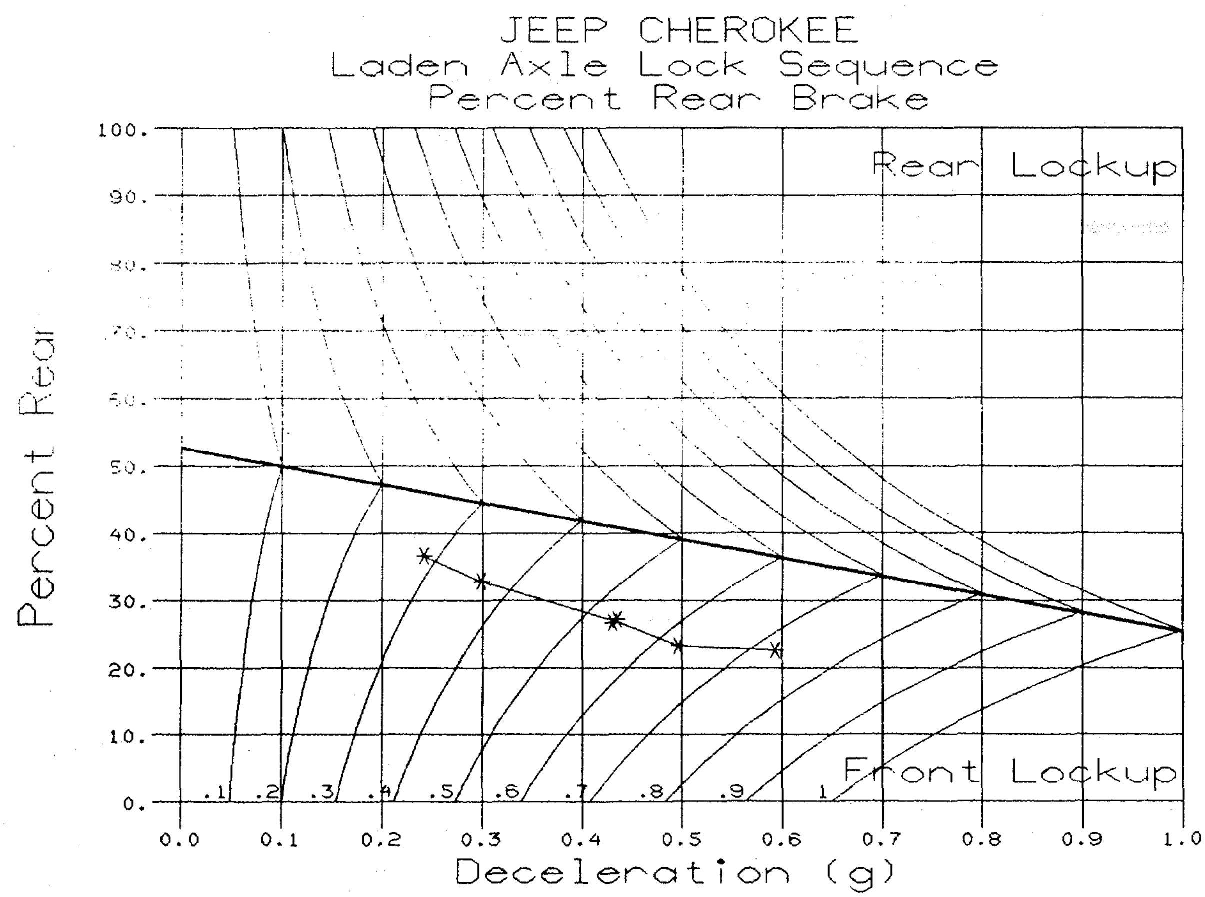

TOYOTA 4RUNNER
Laden Axle Lock Sequence
Braking Efficiency
Rear Lockup
Front Lockup
Efficiency
50.
60.
70.
80.
90.
100.
90.
80.
70.
60.
50.
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Peak Tire/Road Coefficient (mu)

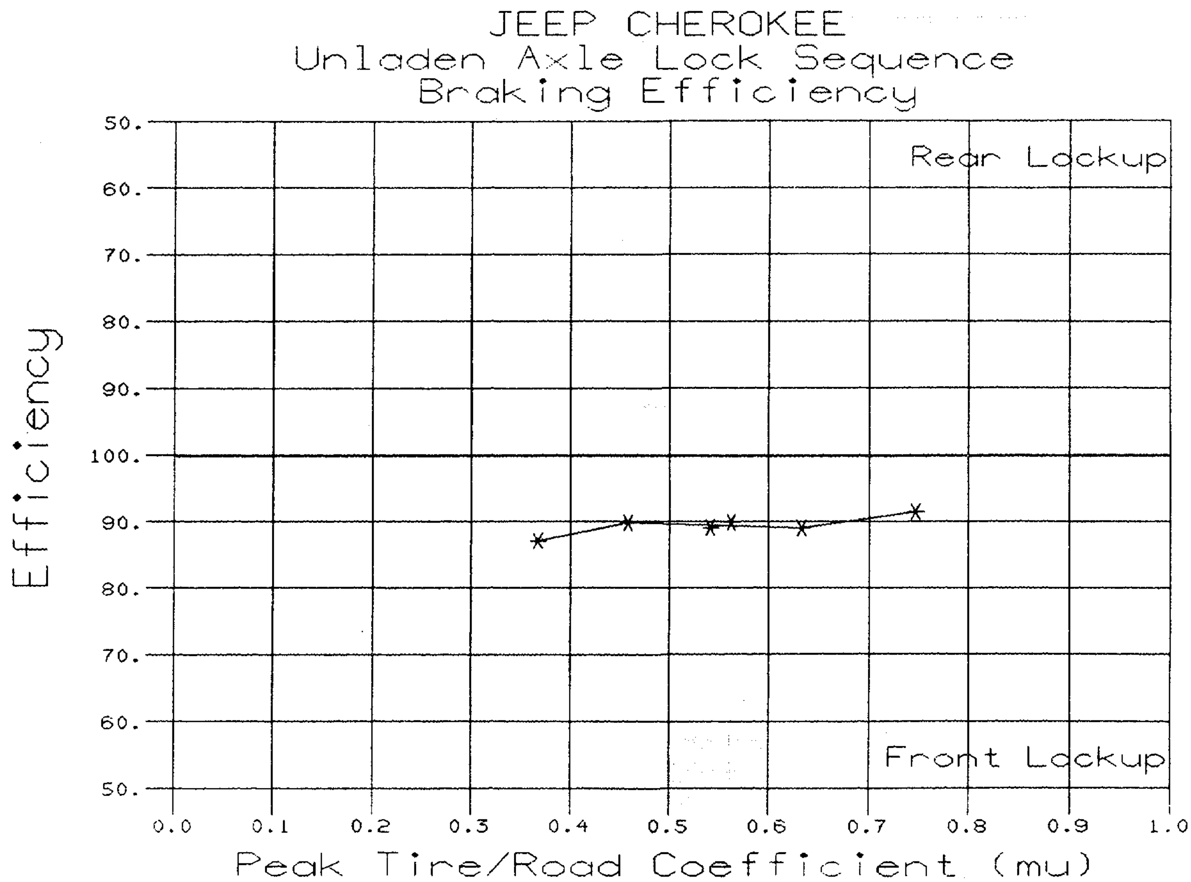

TOYOTA 4RUNNER
Laden Axle Lock Sequence
Percent Rear Brake
Rear Lockup
Front Lockup
Percent Rear
100.
90.
80.
70.
60.
50.
40.
30.
20.
10.
0.
.1
.2
.3
.4
.5
.6
.7
.8
.9
1
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Deceleration (g)


TOYOTA 4RUNNER
Unladen Axle Lock Sequence
Braking Efficiency
Rear Lockup
Front Lockup
Efficiency
50.
60.
70.
80.
90.
100.
90.
80.
70.
60.
50.
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Peak Tire/Road Coefficient (mu)

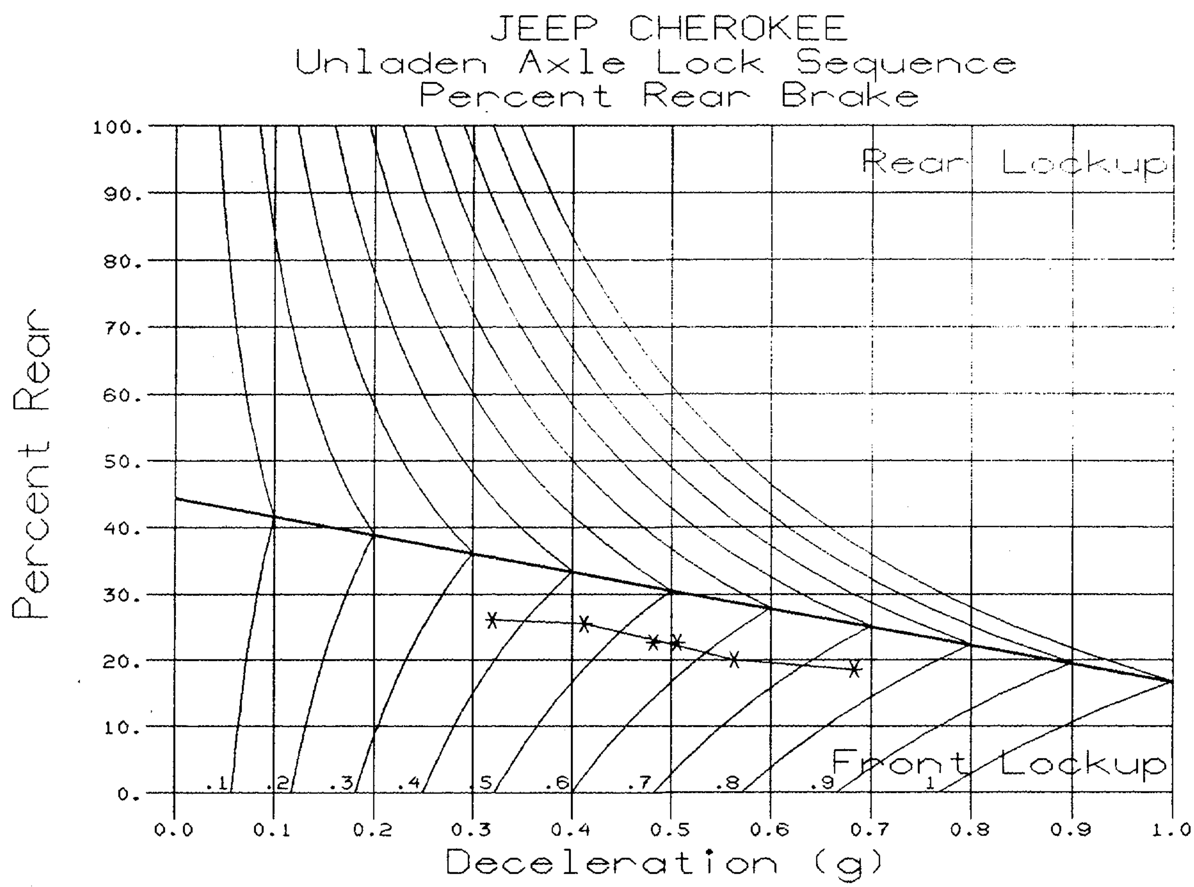

TOYOTA 4RUNNER
Unladen Axle Lock Sequence
Percent Rear Brake
Rear Lockup
Front Lockup
Percent Rear
100.
90.
80.
70.
60.
50.
40.
30.
20.
10.
0.
.1
.2
.3
.4
.5
.6
.7
.8
.9
1
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Deceleration (g)


JEEP CHEROKEE
Laden Axle Lock Sequence
Braking Efficiency
Rear Lockup
Front Lockup
Efficiency
50.
60.
70.
80.
90.
100.
90.
80.
70.
60.
50.
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Peak Tire/Road Coefficient (mu)


JEEP CHEROKEE
Laden Axle Lock Sequence
Percent Rear Brake
Rear Lockup
Front Lockup
Percent Rear
100.
90.
80.
70.
60.
50.
40.
30.
20.
10.
0.
.1
.2
.3
.4
.5
.6
.7
.8
.9
1
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Deceleration (g)



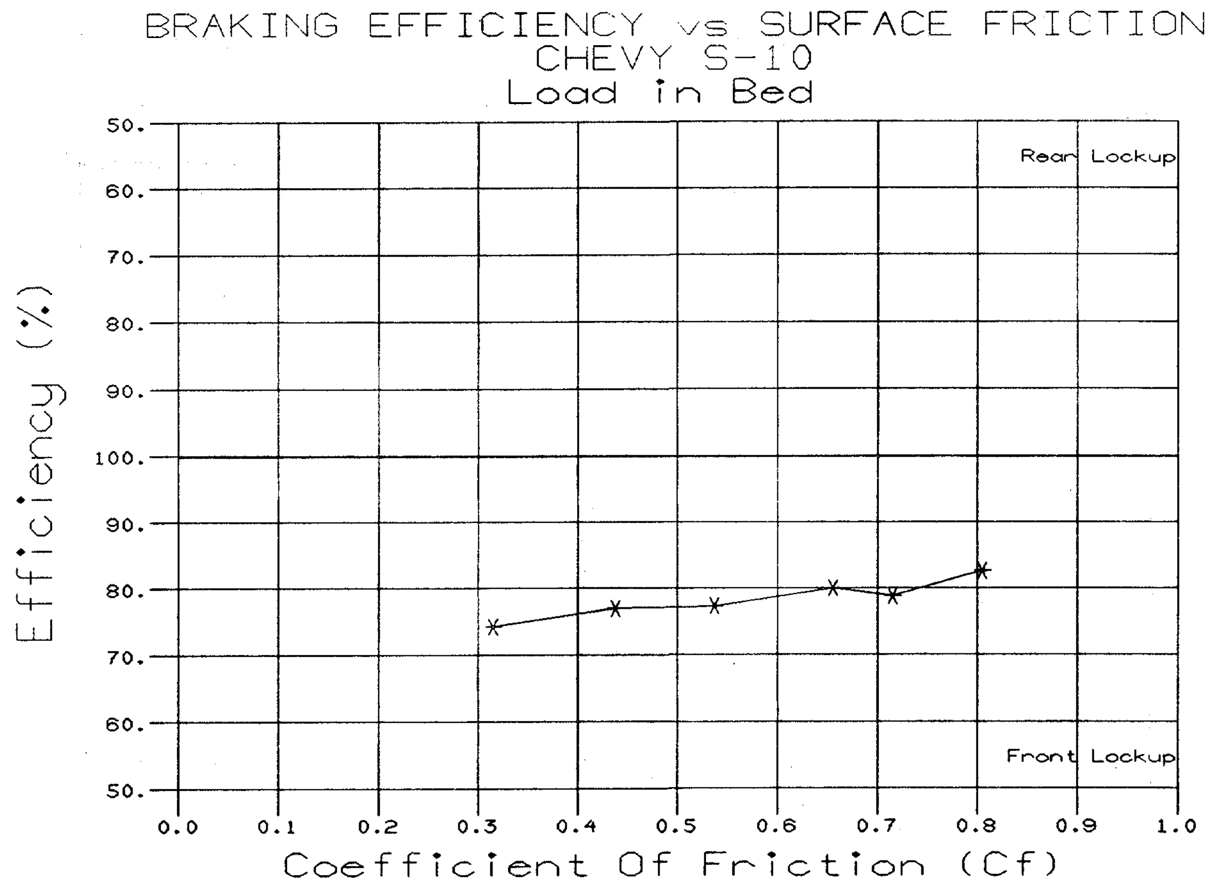
JEEP CHEROKEE
Unladen Axle Lock Sequence
Braking Efficiency
Rear Lockup
Front Lockup
Efficiency
50.
60.
70.
80.
90.
100.
90.
80.
70.
60.
50.
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Peak Tire/Road Coefficient (mu)

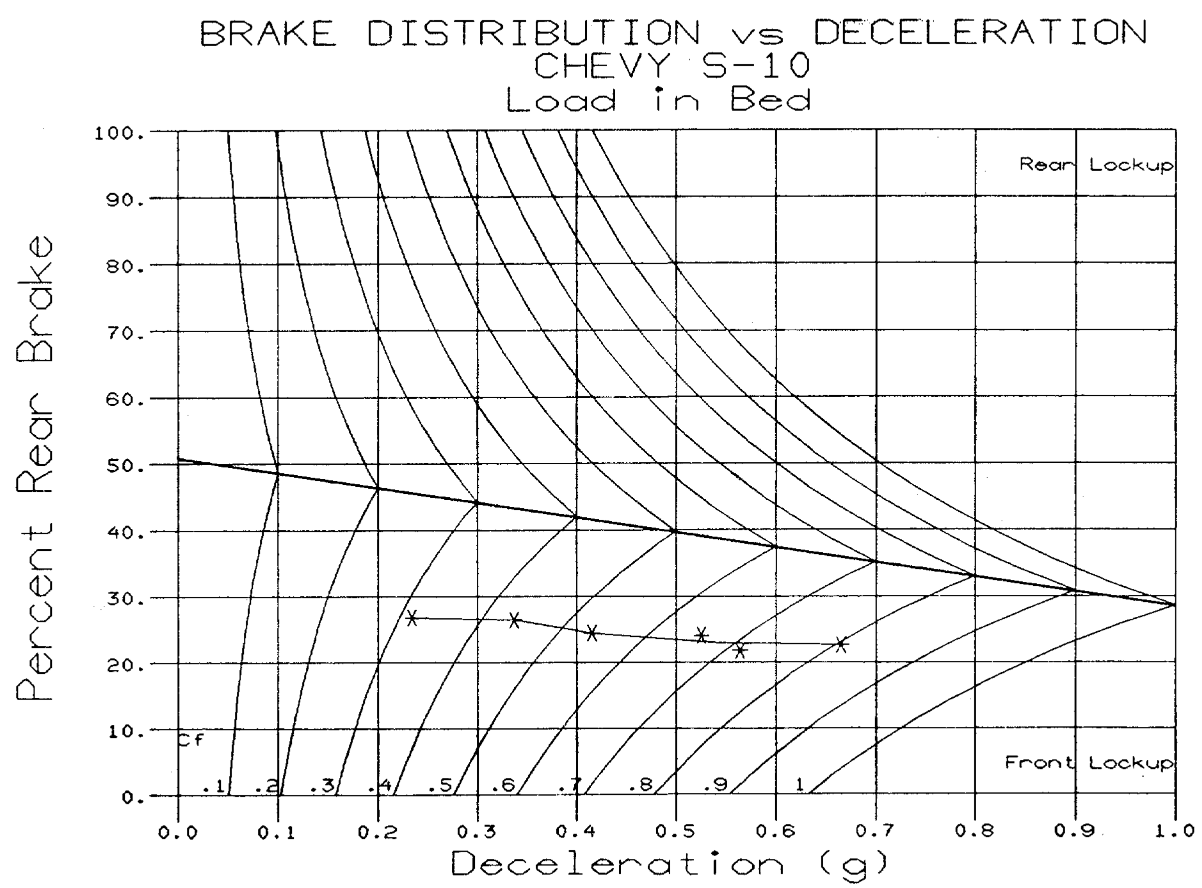


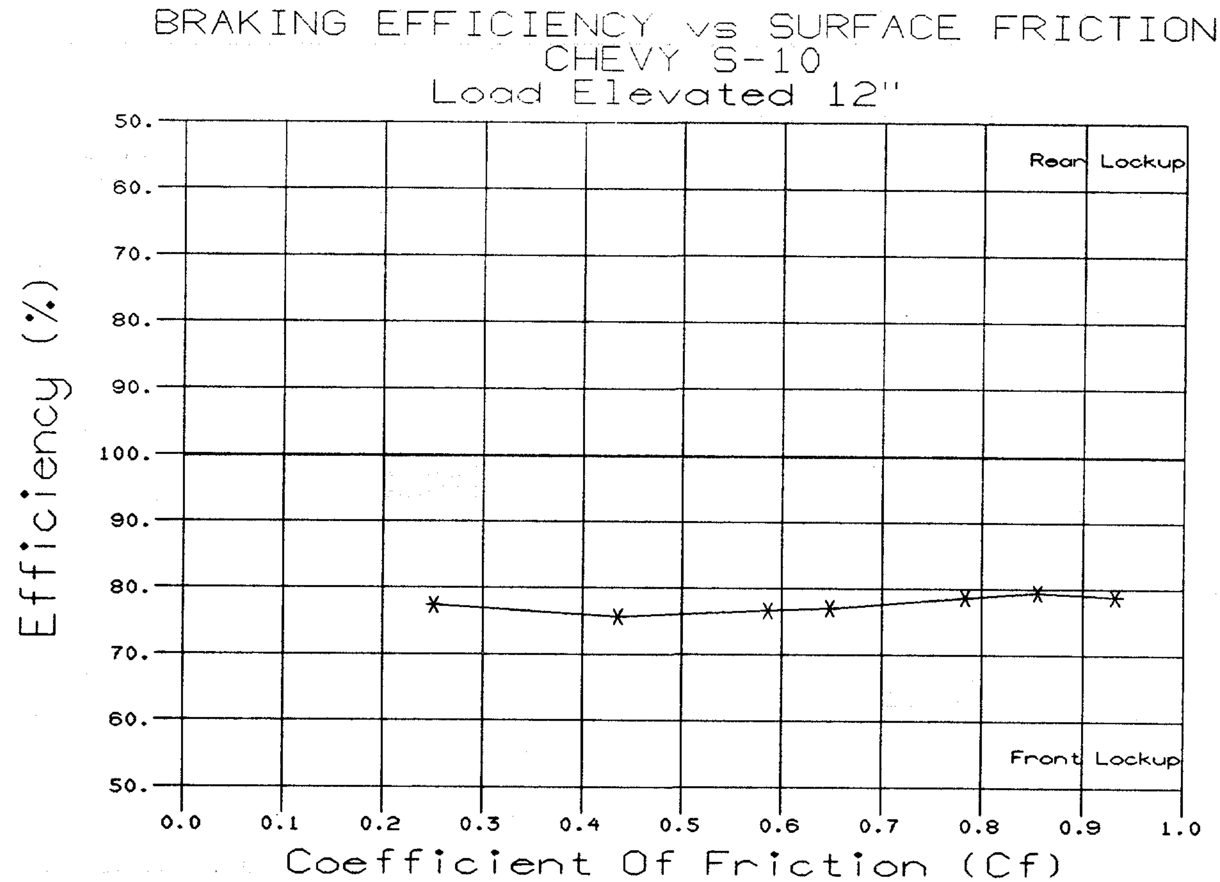
JEEP CHEROKEE
Unladen Axle Lock Sequence
Percent Rear Brake
Rear Lockup
Front Lockup
Percent Rear
100.
90.
80.
70.
60.
50.
40.
30.
20.
10.
0.
.1
.2
.3
.4
.5
.6
.7
.8
.9
1
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Deceleration (g)

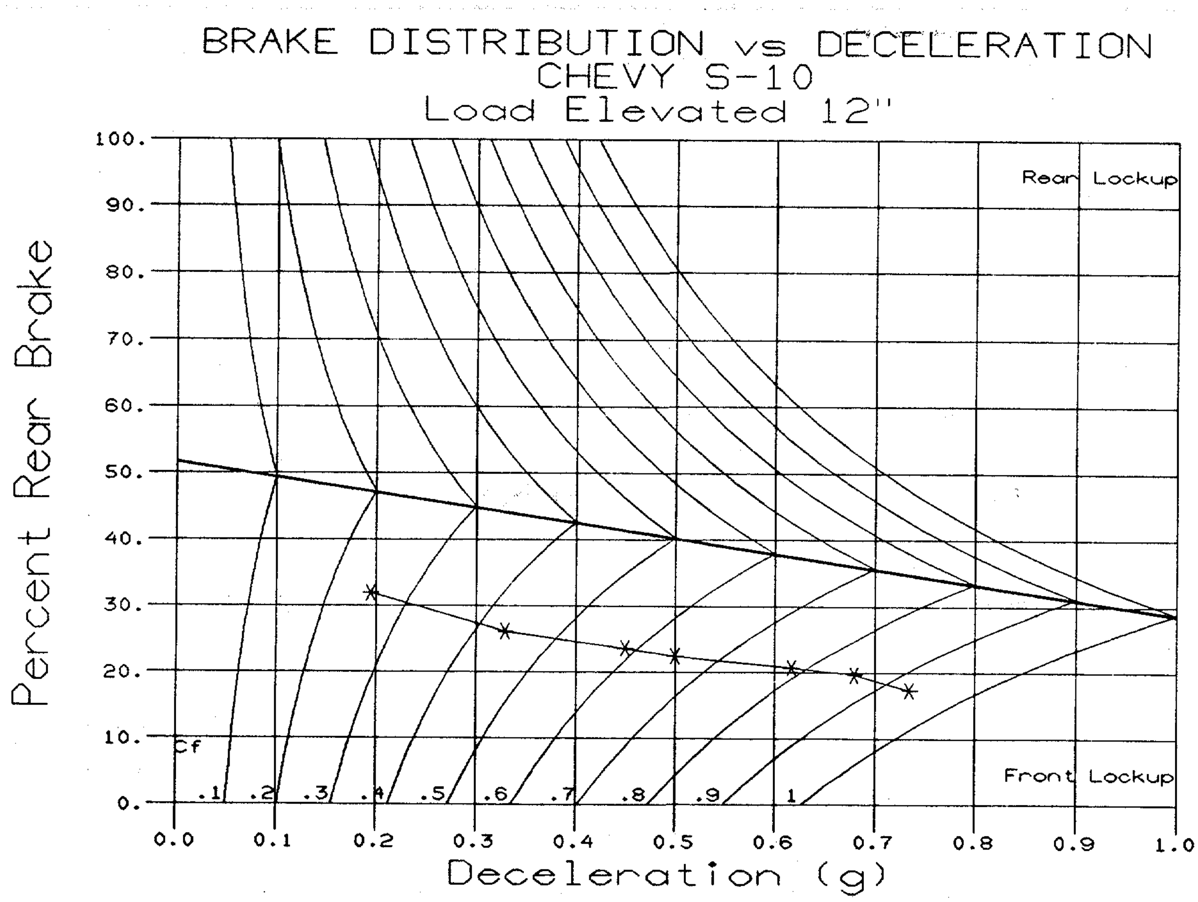
APPENDIX E

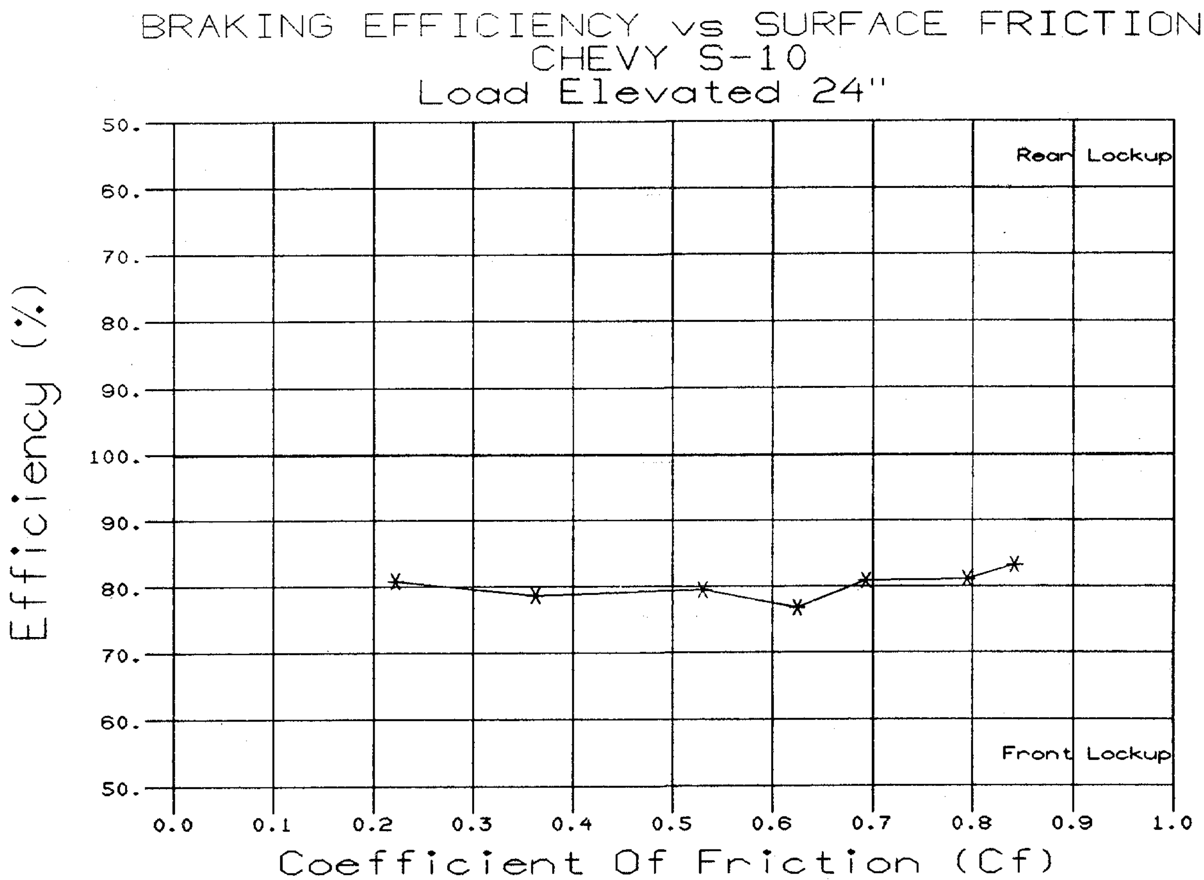
RTP Load Height Tests

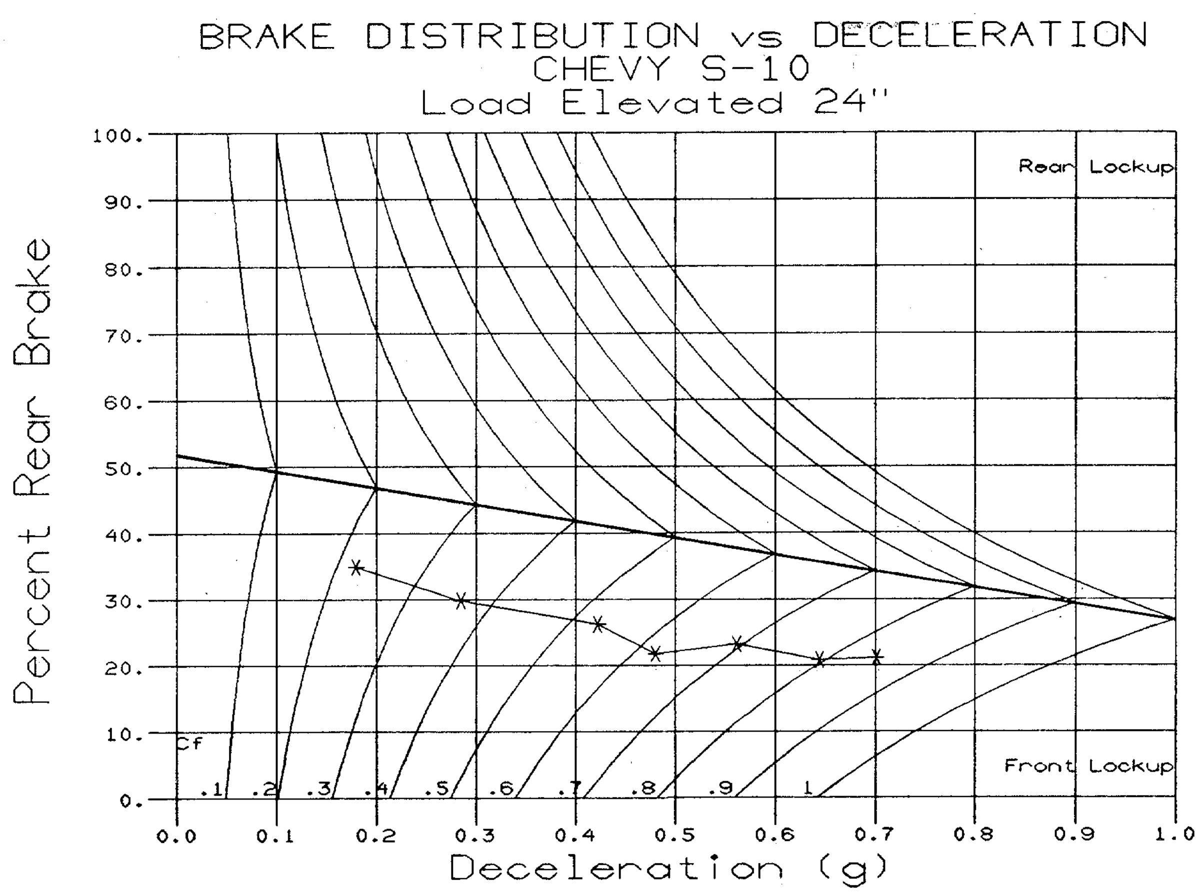

BRAKING EFFICIENCY vs SURFACE FRICTION
CHEVY S-10
Load in Bed
Rear Lockup
Front Lockup
Efficiency (%)
50.
60.
70.
80.
90.
100.
90.
80.
70.
60.
50.
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Coefficient Of Friction (Cf)


BRAKE DISTRIBUTION vs DECELERATION
CHEVY S-10
Load in Bed
Rear Lockup
Front Lockup
Percent Rear Brake
100.
90.
80.
70.
60.
50.
40.
30.
20.
10.
0.
Cf
.1
.2
.3
.4
.5
.6
.7
.8
.9
1
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Deceleration (g)

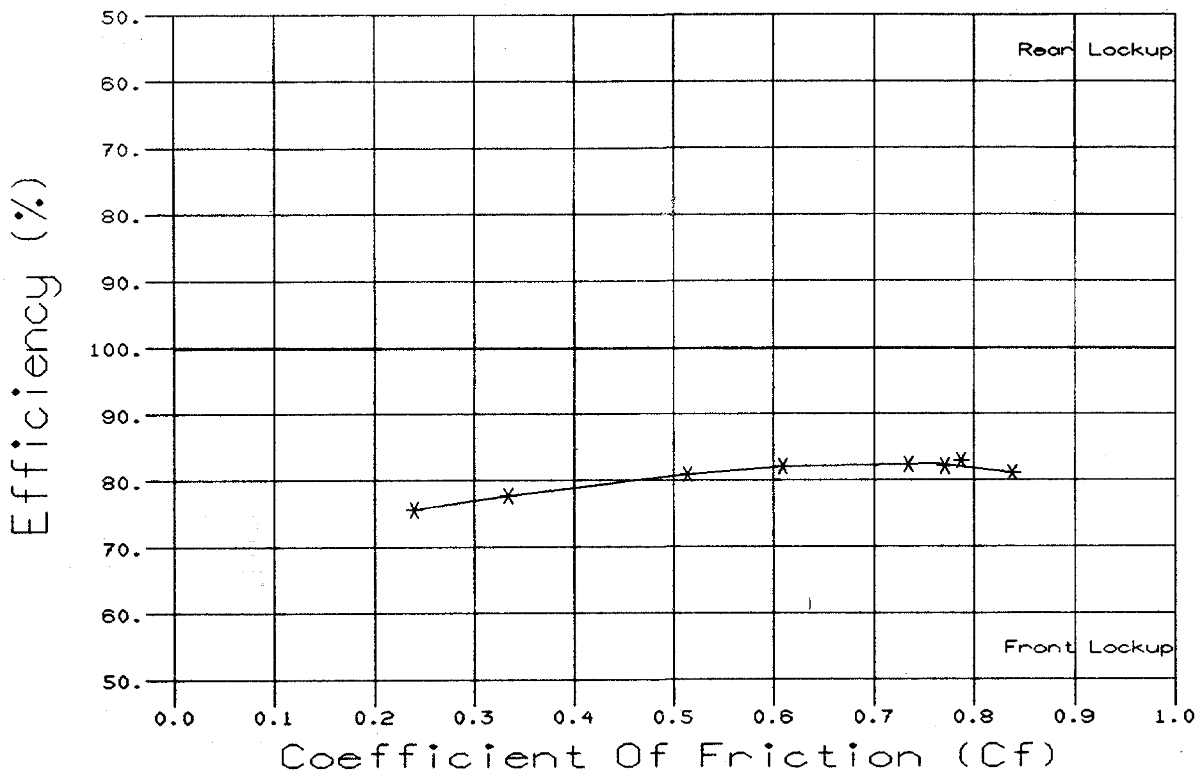

BRAKING EFFICIENCY vs SURFACE FRICTION
CHEVY S-10
Load Elevated 12"
Rear Lockup
Front Lockup
Efficiency (%)
50.
60.
70.
80.
90.
100.
90.
80.
70.
60.
50.
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Coefficient Of Friction (Cf)


BRAKE DISTRIBUTION vs DECELERATION
CHEVY S-10
Load Elevated 12"
Rear Lockup
Front Lockup
Percent Rear Brake
100.
90.
80.
70.
60.
50.
40.
30.
20.
10.
0.
Cf
.1
.2
.3
.4
.5
.6
.7
.8
.9
1
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Deceleration (g)

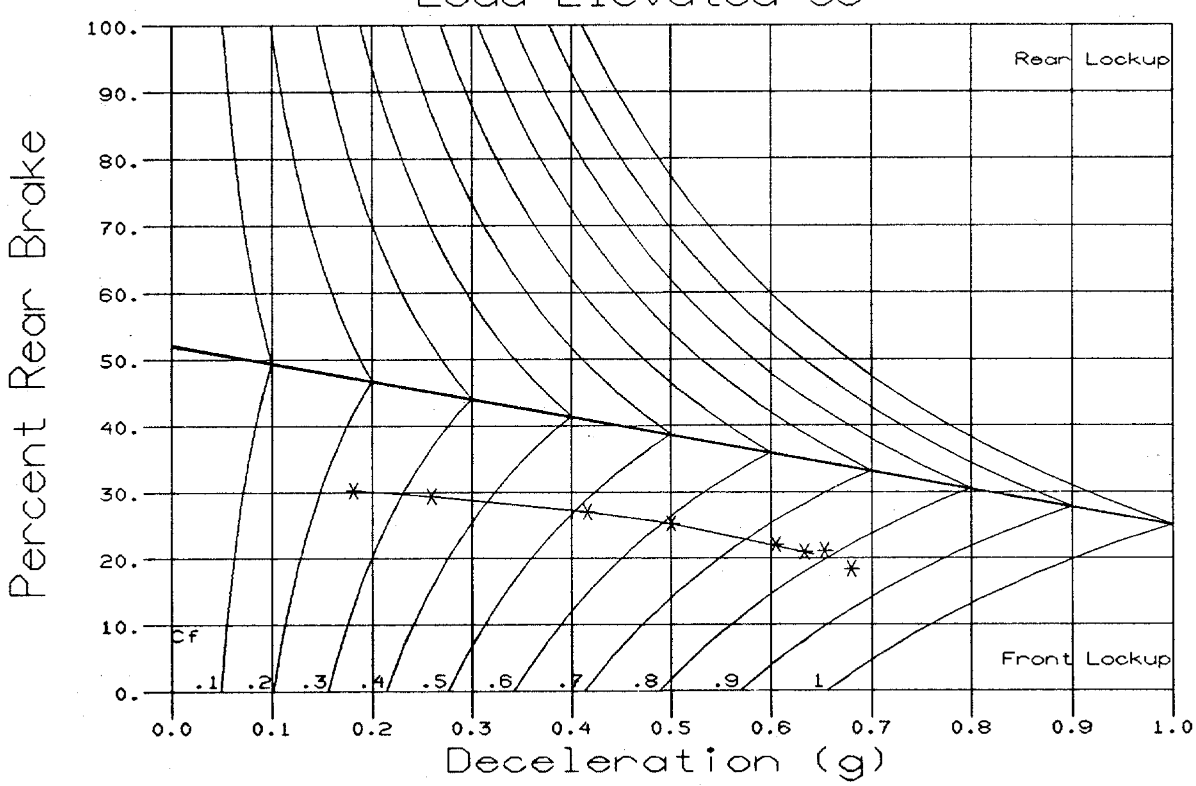

BRAKING EFFICIENCY vs SURFACE FRICTION
CHEVY S-10
Load Elevated 24"
Efficiency (%)
Coefficient Of Friction (Cf)
Rear Lockup
Front Lockup
50.
60.
70.
80.
90.
100.
90.
80.
70.
60.
50.
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0

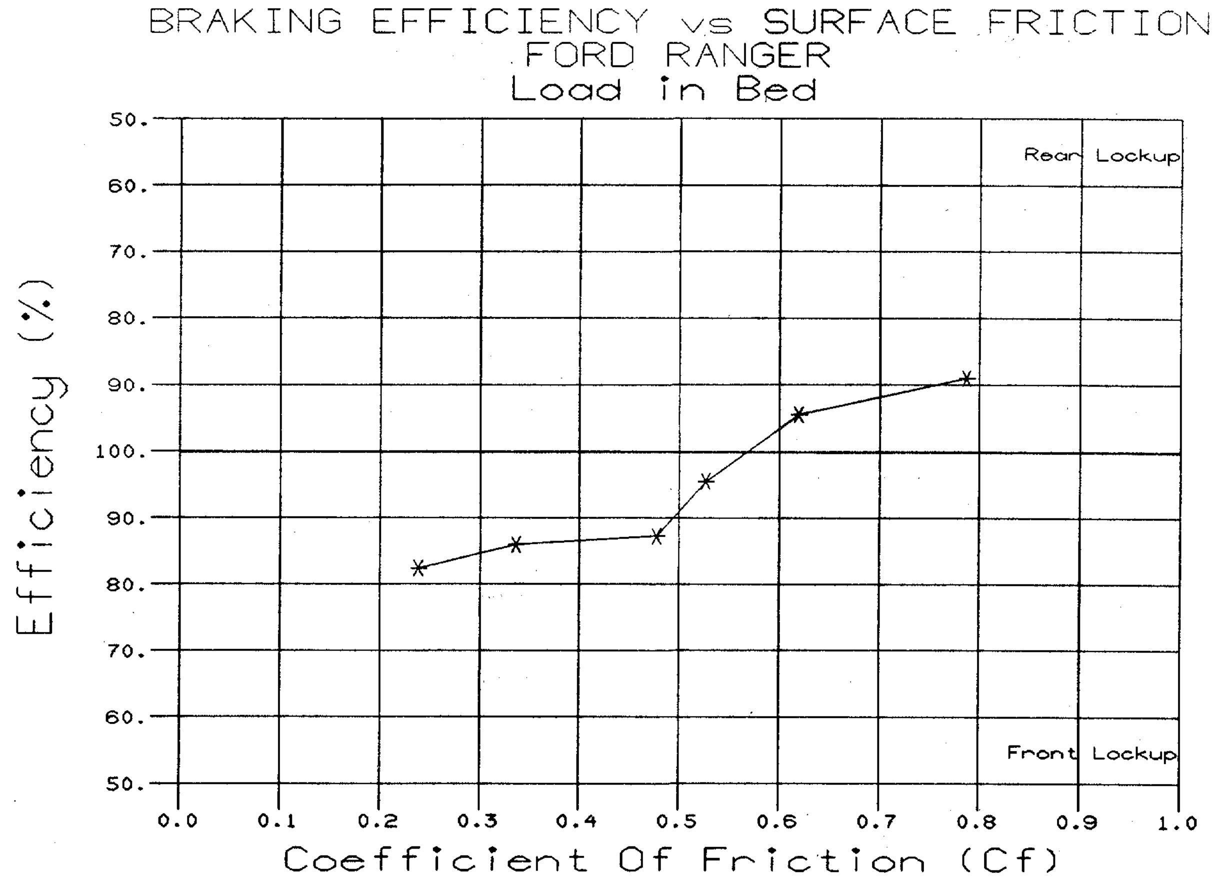

BRAKE DISTRIBUTION vs DECELERATION
CHEVY S-10
Load Elevated 24"
Percent Rear Brake
Deceleration (g)
Rear Lockup
Front Lockup
Cf
.1
.2
.3
.4
.5
.6
.7
.8
.9
1
100.
90.
80.
70.
60.
50.
40.
30.
20.
10.
0.
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0

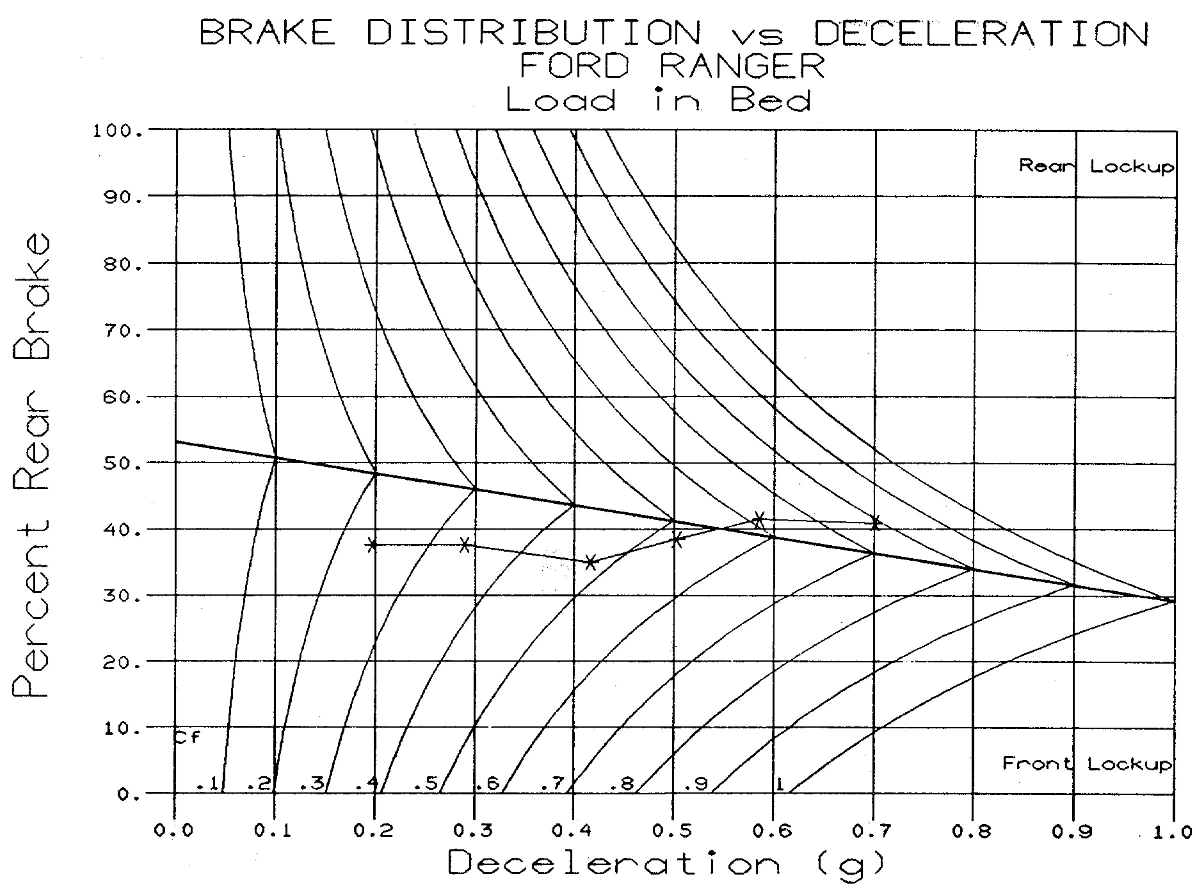
BRAKING EFFICIENCY vs SURFACE FRICTION
CHEVY S-10
Load Elevated 36"

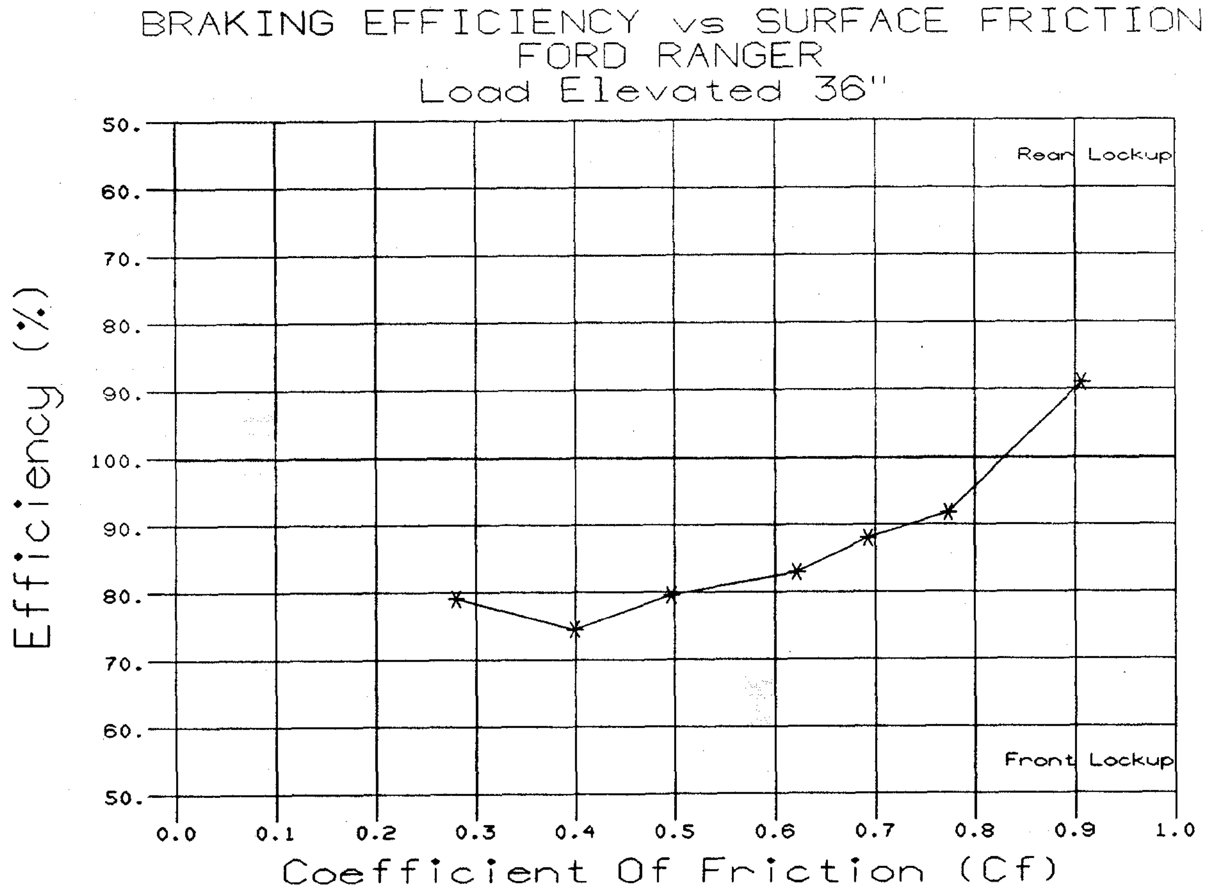


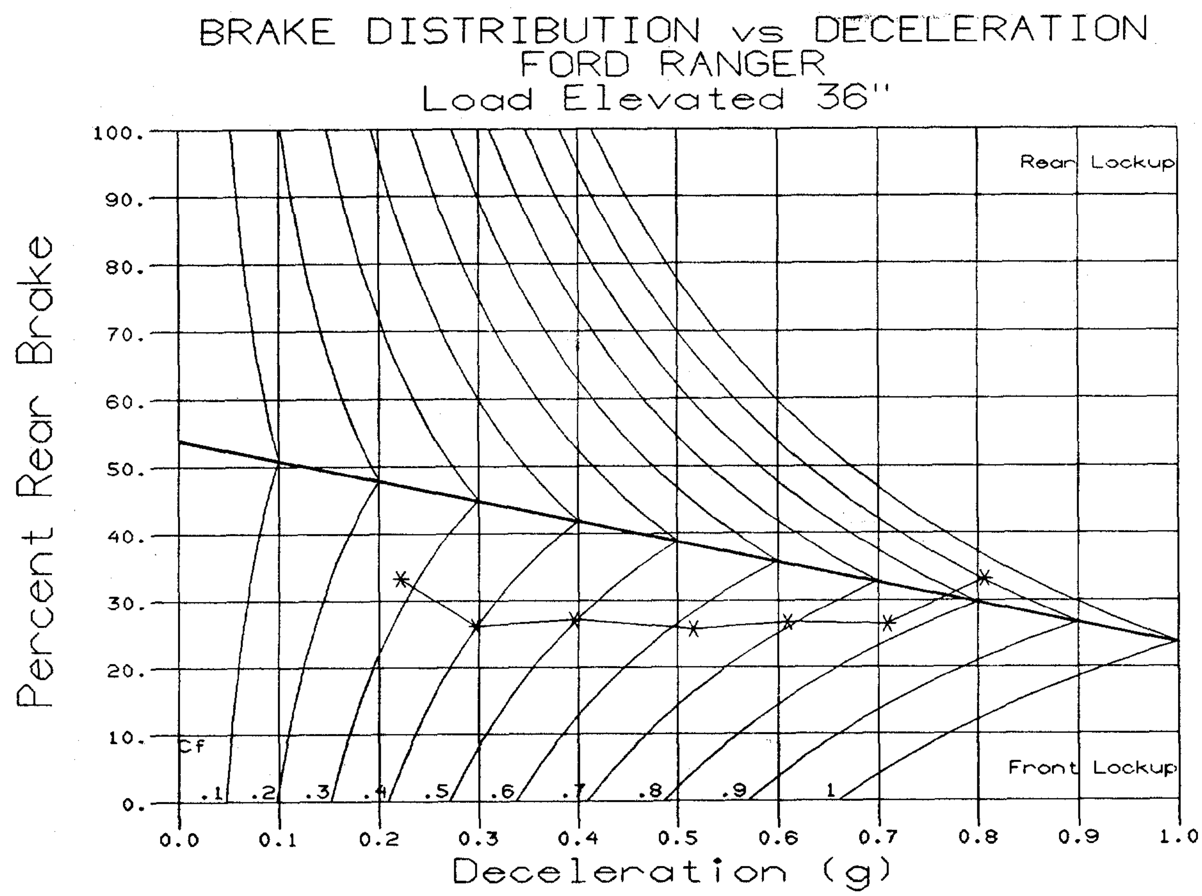
BRAKE DISTRIBUTION vs DECELERATION
CHEVY S-10
Load Elevated 36"




BRAKING EFFICIENCY vs SURFACE FRICTION
FORD RANGER
Load in Bed
Efficiency (%)
Rear Lockup
Front Lockup
Coefficient Of Friction (Cf)

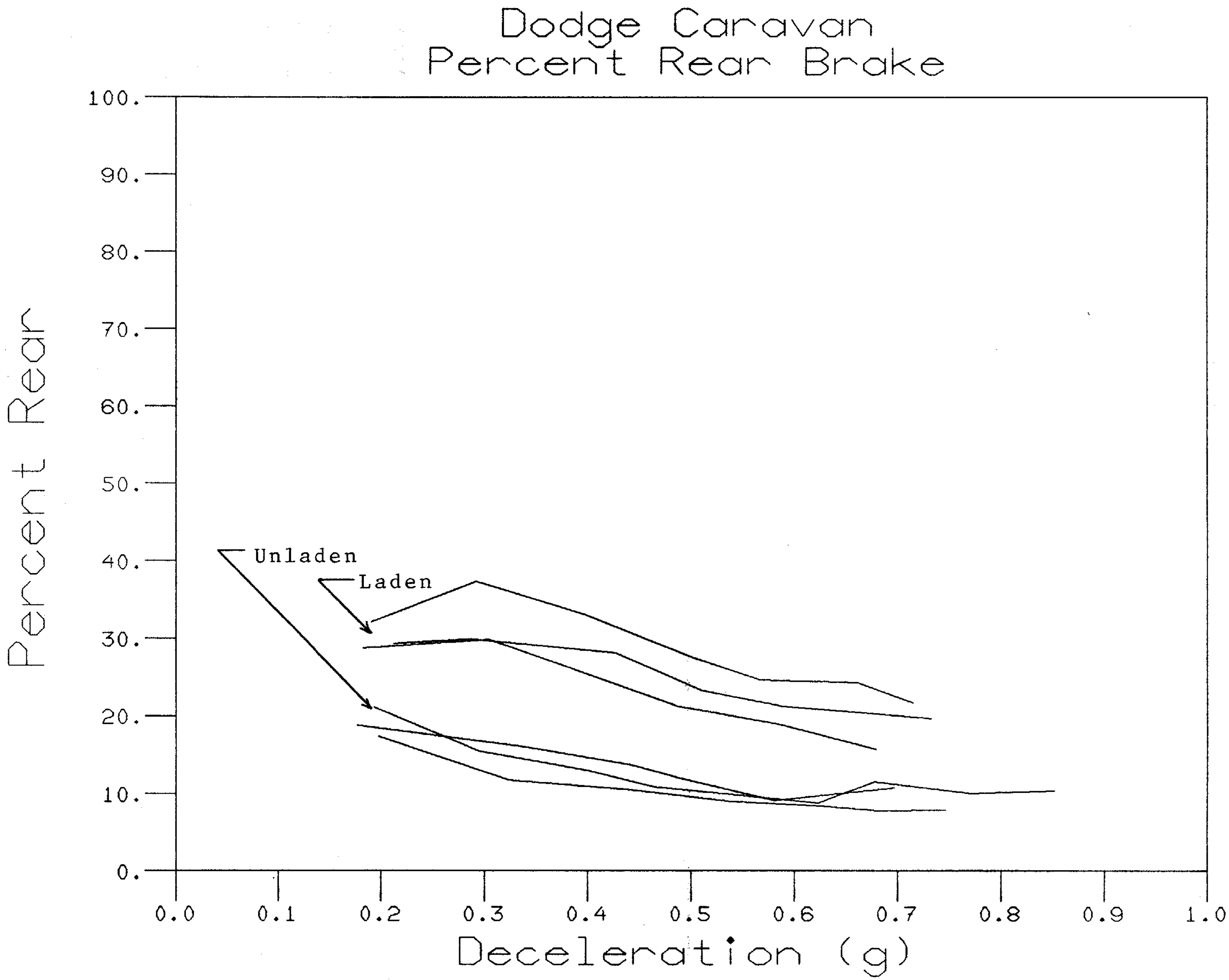

BRAKE DISTRIBUTION vs DECELERATION
FORD RANGER
Load in Bed
Percent Rear Brake
Rear Lockup
Front Lockup
Cf
Deceleration (g)

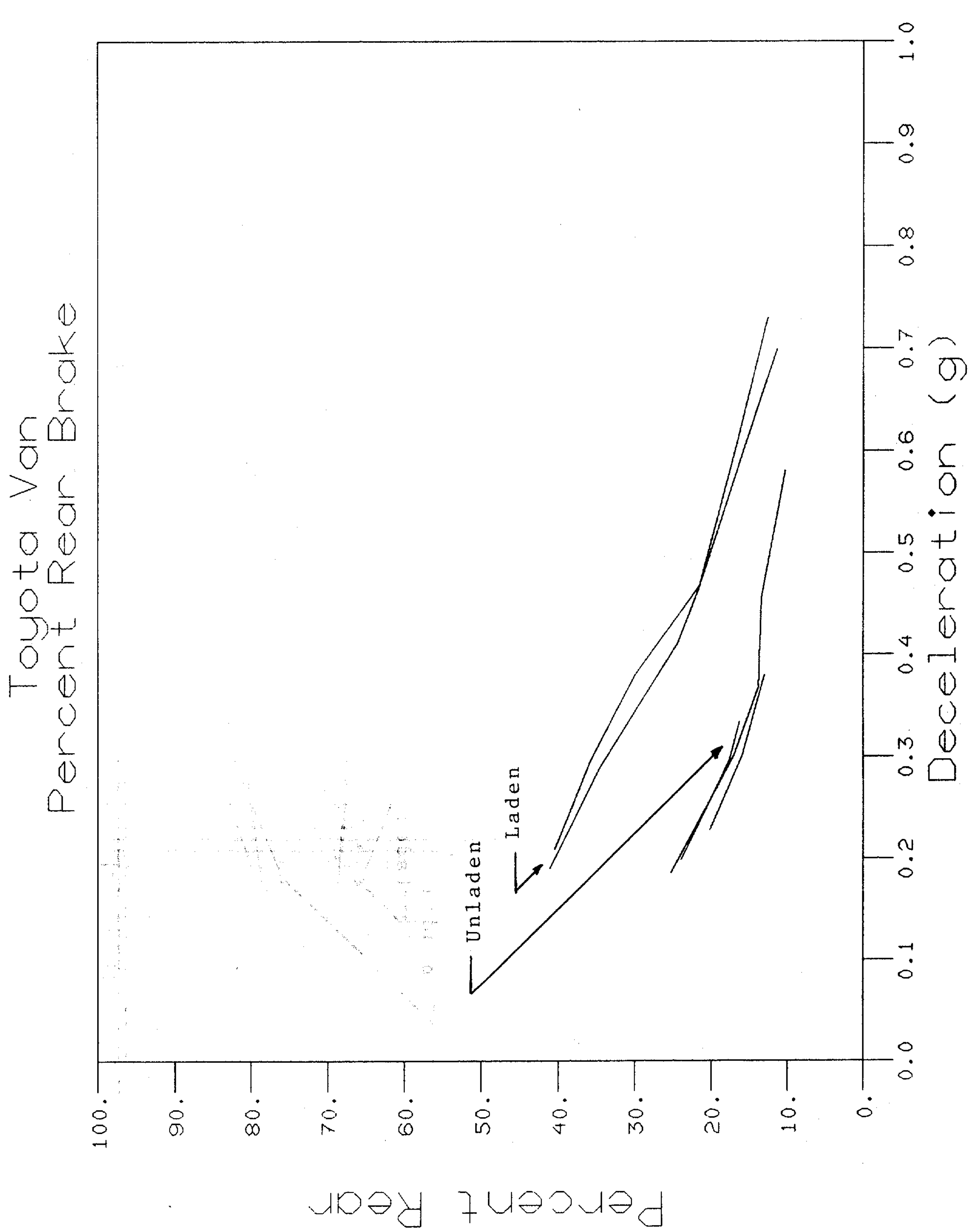

BRAKING EFFICIENCY vs SURFACE FRICTION
FORD RANGER
Load Elevated 36"
Rear Lockup
Front Lockup
Efficiency (%)
50.
60.
70.
80.
90.
100.
90.
80.
70.
60.
50.
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Coefficient Of Friction (Cf)


BRAKE DISTRIBUTION vs DECELERATION
FORD RANGER
Load Elevated 36"
Rear Lockup
Front Lockup
Percent Rear Brake
100.
90.
80.
70.
60.
50.
40.
30.
20.
10.
0.
Cf
.1
.2
.3
.4
.5
.6
.7
.8
.9
1
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Deceleration (g)

APPENDIX F

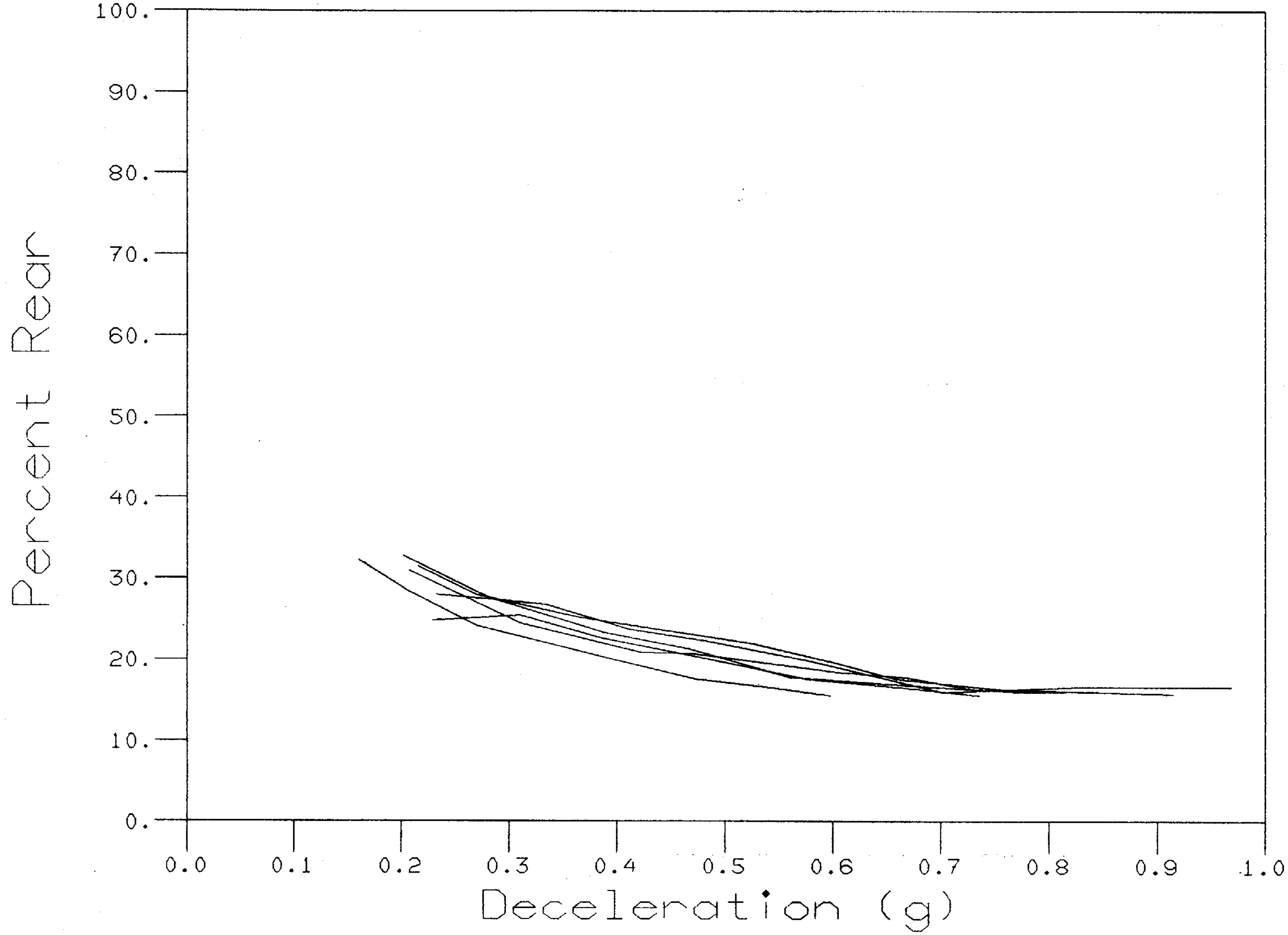
RTP Tests Composites

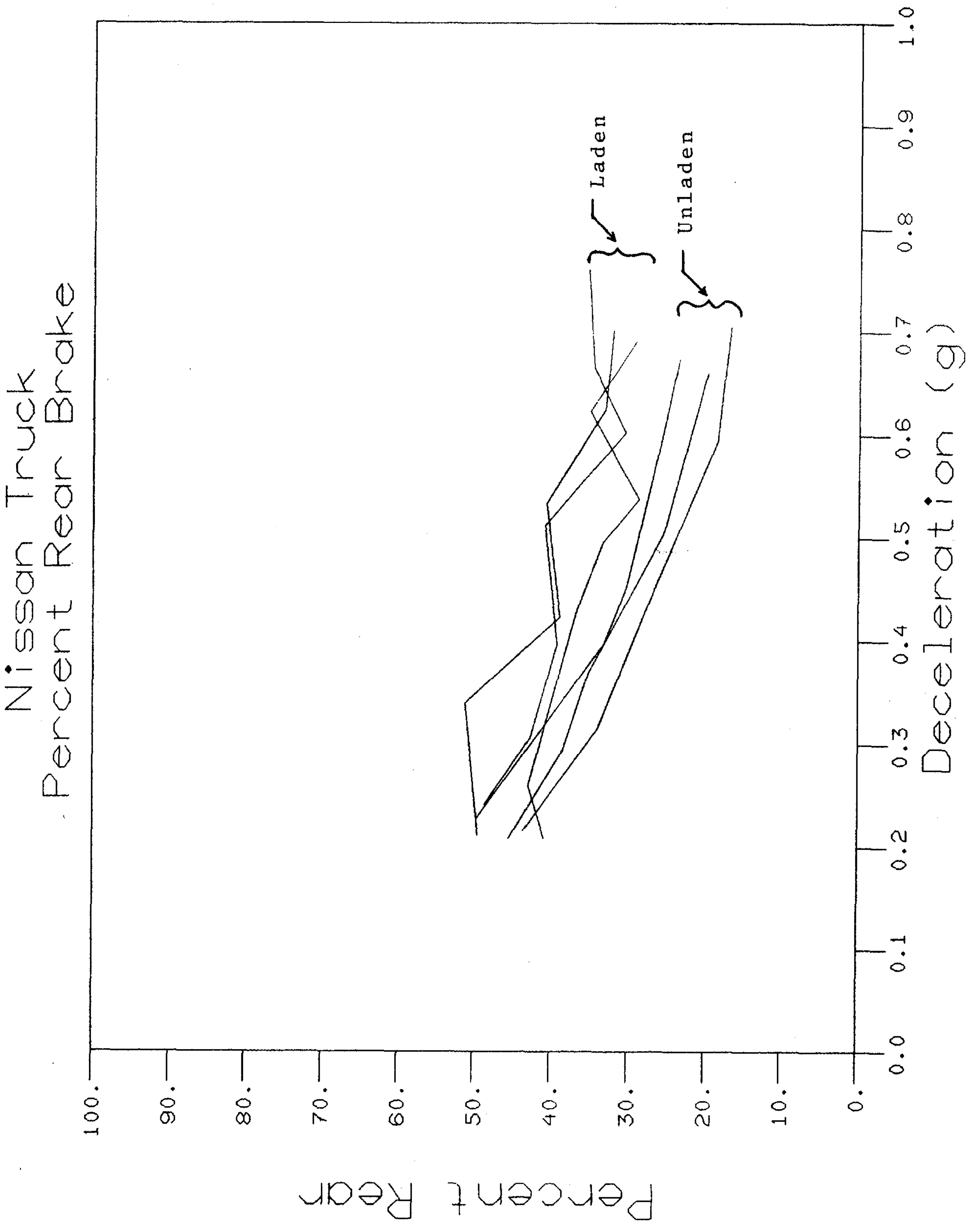

Dodge Caravan
Percent Rear Brake
Percent Rear
Deceleration (g)
Unladen
Laden
100.
90.
80.
70.
60.
50.
40.
30.
20.
10.
0.
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0

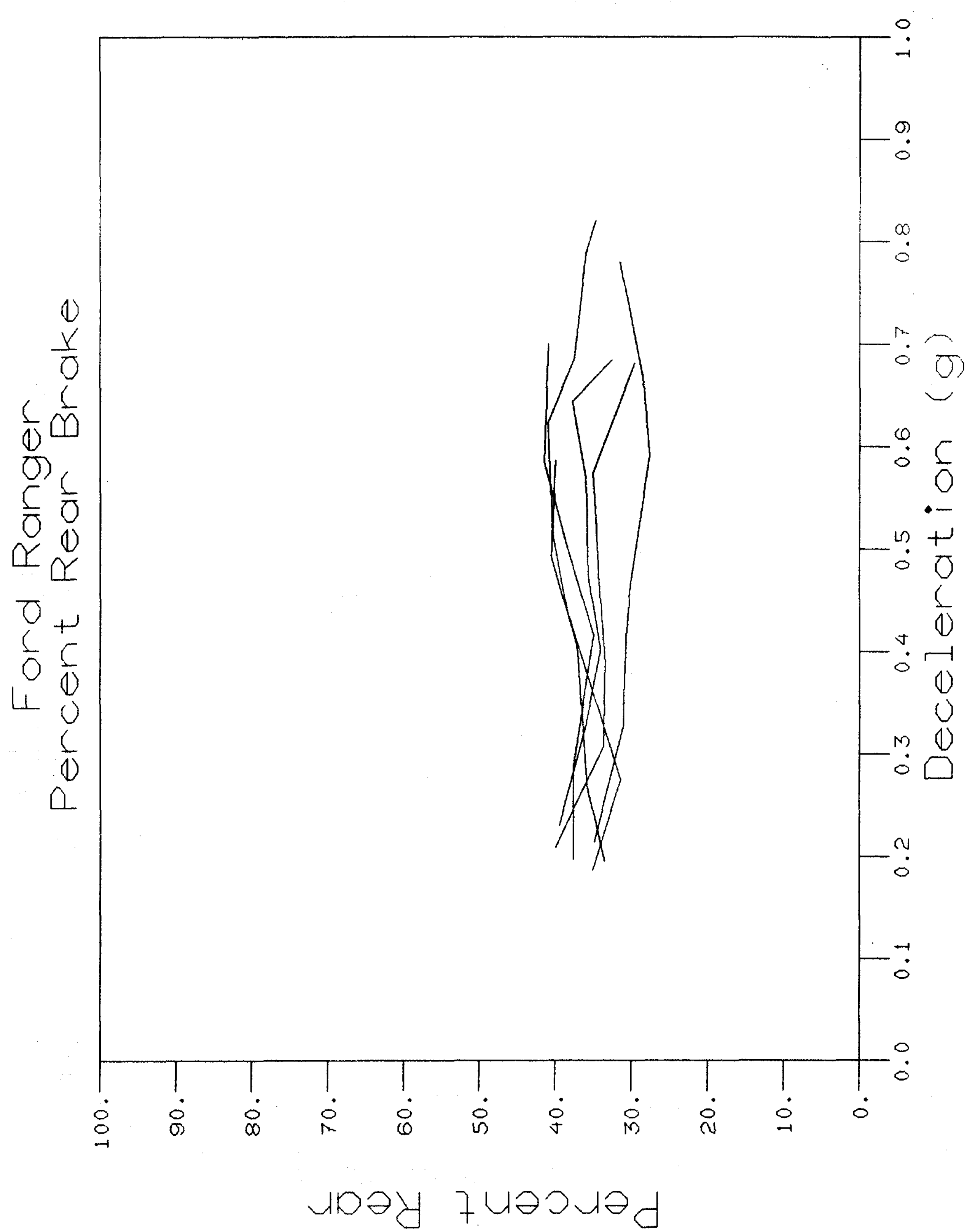


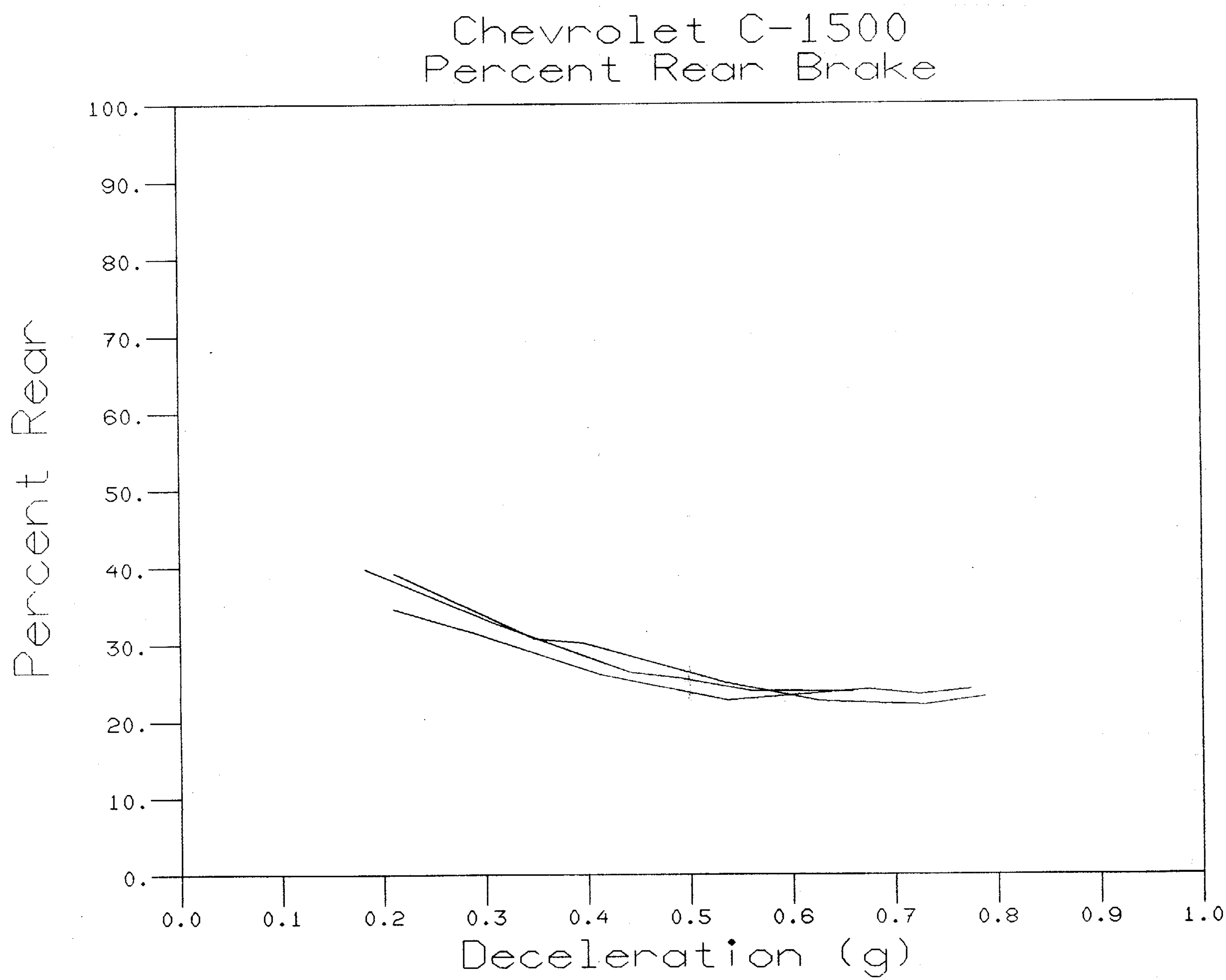
Toyota Van
Percent Rear Brake
Percent Rear
Deceleration (g)
Unladen
Laden
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
0.
10.
20.
30.
40.
50.
60.
70.
80.
90.
100.

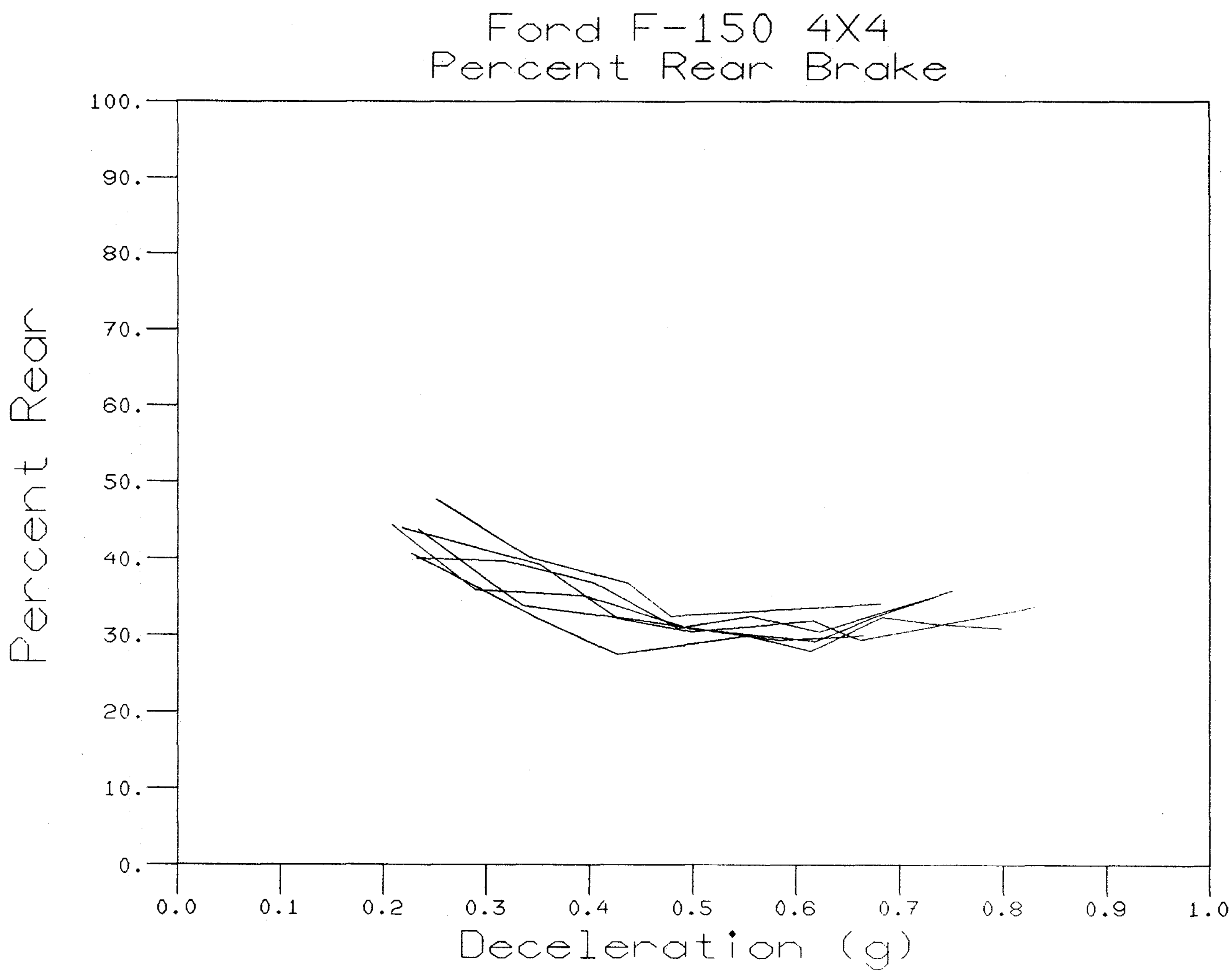
Chevrolet Astro
Percent Rear Brake

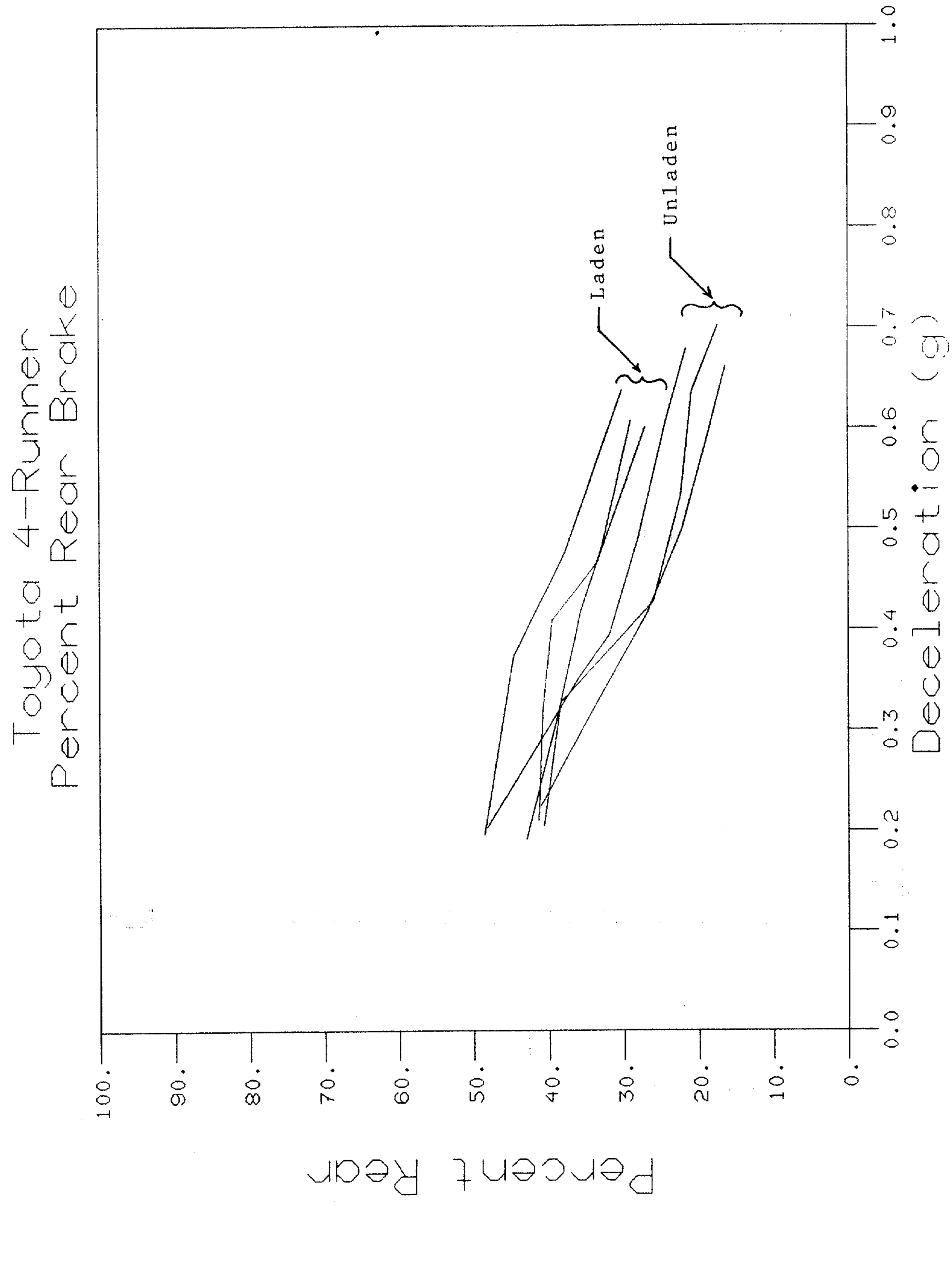


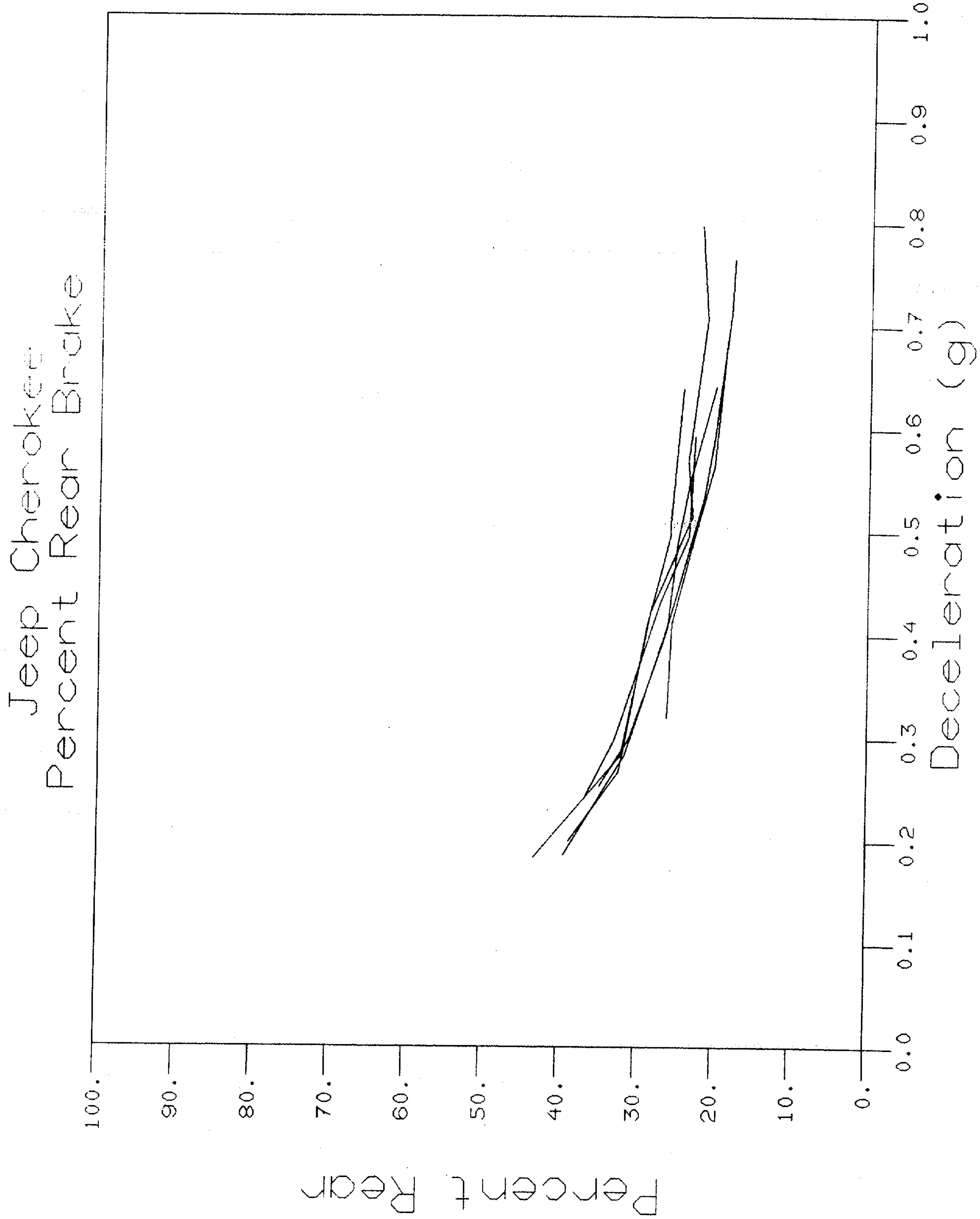

Nissan Truck
Percent Rear Brake
Laden
Unladen
Deceleration (g)
Percent Rear
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
0.
10.
20.
30.
40.
50.
60.
70.
80.
90.
100.


Ford Ranger
Percent Rear Brake
Deceleration (g)
Percent Rear
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
0.
10.
20.
30.
40.
50.
60.
70.
80.
90.
100.


Chevrolet C-1500
Percent Rear Brake
Percent Rear
100.
90.
80.
70.
60.
50.
40.
30.
20.
10.
0.
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Deceleration (g)


Ford F-150 4X4
Percent Rear Brake
Percent Rear
Deceleration (g)
100.
90.
80.
70.
60.
50.
40.
30.
20.
10.
0.
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0


Toyota 4-Runner
Percent Rear Brake
Percent Rear
Deceleration (g)
Laden
Unladen
0. 10. 20. 30. 40. 50. 60. 70. 80. 90. 100.
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0



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